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RETAINING WALLS.

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PROF. WEYRAUCH, of the Stuttgart Polytechnikum has published in the *Zeitschrift für Bankunde*, Band, 1 Heft 2, 1878, a new theory of the retaining wall, which merits notice, even by those who may regard the subject as worn threadbare, at least from a practical standpoint.

It is to be observed that all theories of retaining walls should agree if the hypotheses upon which they are founded are taken the same. Unfortunately different assumptions have been made by different authors, so that all the formulæ deduced do not agree. Thus, the direction of the earth thrust with respect to the normal to the wall, has been taken at angles varying from o to the angle of friction, by various writers; of course with discordant results.

It is therefore most essential in treating this subject, that hypotheses be taken in accordance with facts, and that the preliminary steps be carefully demonstrated. If, however, data is wanting, so that some indetermination necessarily exists, then it should be exposed fairly, and not set aside or replaced by some bare assumption, however confidently supported, though it may be by great names.

In endeavoring to carry out this plan in this paper, a portion of Weyrauch's new theory will be used, and his final results deduced from some simple considerations; after which the identity of these results in certain cases with those given by Rankine will be shown; and finally, the subject of the direction of the earth thrust against the wall, and the consequences resulting from various directions will be closely examined.

In this article, *we consider the earth as a homogeneous and incompressible mass, made up of little grains, possessing the resistance to sliding over each other called friction, but without cohesion.* We are well aware that the practical engineer must consider other influences, as affecting the stability of retaining walls, than the pressure of a dry homogeneous earth, devoid of cohesion; thus, the ground may become saturated with water, and this water may freeze, expanding in the act with great force; again, heavy loads may pass over the earth causing great vibrations* which cannot be included in any formulæ; still, if the engineer knows the exact influence of dry earth, not subjected to

* Trautwine states in experiments in an upper room of a strongly built dwelling, with dry sand retained by wooden walls, "that the tremor produced by passing vehicles in the streets, by the shutting of doors, and walking about the room, sufficed to gradually produce leaning in walls of considerably more than twice the mere balancing stability when quiet." See his *Engineer's Pocket-Book*, p. 333.

tremor, on walls, he should be better able to design them to withstand *all* the destructive forces to which they may be subjected than when he has no such knowledge. Let Fig. 1 represent a vertical section of a portion of the retaining wall ABCD and the earth ABF behind it, whose length, ⊥ plane of paper, is unity.

Assumption. We assume that the earth behind the wall has a tendency to slide along some *plane surface of rupture*, as Ab_1, Ab_2 . . . .

No proof is given of this assumption, but we shall find that, in certain cases,

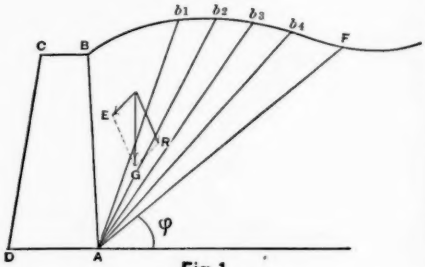

Fig. 1.

it gives identical results with theories (as Rankine's) that are not based on any principle but the known laws of friction, and hence must be correct for those cases. Afterwards, we may infer that the principle is, at least, approximately correct, for certain cases that cannot be solved by Rankine's method. The graphical method too is absolutely dependent on this assumption, so that it is important to establish it.

Coulomb's Wedge of Maximum Thrust. Let us consider the triangular prisms BAb_1, BAb_2, . . ., as regards sliding along their inclined bases Ab_1, Ab_2, ... Now if AF is at the natural slope of the earth, the tendency of the prism BAF to slide along AF would exactly be balanced by friction, as is well known. But if we consider other possible planes of rupture, lying above AF, as Ab_4, Ab_5, . . ., we see that unless the wall offers a resistance, that sliding along some one of these planes must occur.

Now it is plain, that on our hypothesis of a *plane* of rupture, that sliding *may* occur along *any one* of the planes Ab unless the wall can resist this tendency to slide.

Let us suppose the resistance of the wall to steadily increase from zero, as we consider prisms that exercise greater and greater thrusts. Now for any special value of this resistance we see that the prisms that cause a less thrust cannot slide; but those requiring a greater resistance can slide, for it is only a certain resistance that prevents them from sliding along their bases. It follows that when stability is assured, that the resistance of the wall must be sufficient to keep the prism which exercises the maximum thrust from sliding; whence follows the principle that the *true* thrust on the wall is that caused by the wedge or prism which gives a maximum thrust, the base of this prism being called the surface of rupture.

This principle is due to Coulomb, and has long served as the basis of theories of earth pressure.

The proof above has been made as plain as possible, for no less an authority than Winkler asserts that no direct, satisfactory proof of Coulomb's wedge of maximum thrust has ever been given.

Some have assumed, that if the stability of the wall against overturning is to be considered, that the wedge causing the maximum *moment* about the outer toe of the wall is the true prism of rupture. But it is plain, that if this wedge is not the one which causes the greatest thrust, that sliding must necessarily occur down the plane corresponding to the greatest thrust. So that the latter thrust is necessarily exerted against the wall, and is the only true and actual one.

Let BAb_2 represent this wedge of maximum thrust; call its weight G, the thrust against the wall E, and the pressure on the plane Ab_2, R. Now it is well known that E and R cannot make angles with the normals to the planes upon which they act greater than the angle of friction, φ of earth on earth. If the friction of the earth on the wall is greater than φ, still a thin layer of earth will go with the wall if it moves, and this layer, rubbing against the remaining earth, can only cause the friction of earth on earth. If the friction of earth on wall is less than that of earth on earth, then E cannot make an angle with the normal to

the wall greater than this angle of friction of earth on wall.

If the wall is supposed perfectly smooth then E must act at right angles to its surface.

In practice, the walls are generally rough, but to complete the subject theoretically, perfectly smooth walls should be included, as special cases, in the formulæ deduced. It is to frame such *general formulæ* that we have resorted to the above hypothesis of a plane surface of rupture.

Referring to Fig. 1, we remark that the prism BAb_2 cannot slide down the plane Ab_2 until the entire frictional resistance of this plane is brought into play; whence it follows that R makes the angle φ with the normal to the plane, its direction lying nearer the vertical than the normal. If, however, the wall is subjected to a thrust from left to right in Fig. 1, due to some agency, as earth, water, etc., acting on CD from the left, and this thrust is just sufficient to cause a sliding of some prism BAb up Ab, then the direction of R on this plane will make an angle φ with the normal, though it will now lie on the other side of the normal to its first position, since the plane now resists motion upwards and not downwards as hitherto. Further, that plane is the true surface of rupture whose corresponding prism causes the *least* resistance to sliding of any conceivable prism, as is sufficiently evident.

A graphical construction will render very apparent the use of Coulomb's principle. Thus, let the right part of

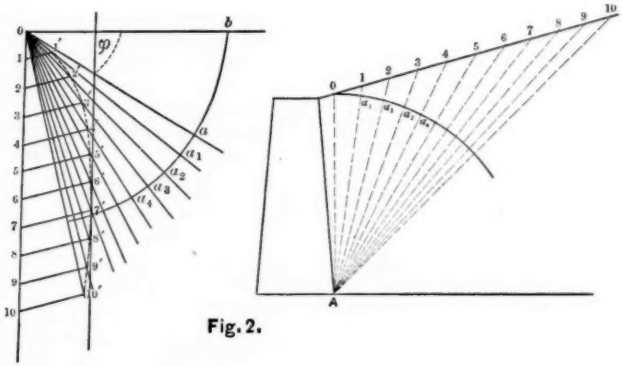

Fig. 2.

Fig. 2 represent a section of a retaining wall and the earth behind it, having the uniform top slope 0 10.

Let A0 represent a vertical plane perpendicular to the plane of the paper, one unit in length; required the pressure the earth exerts on that plane. Lay off the distances 01, 12, ... (equal or unequal) along the top slope, draw the lines A0, A1, A2, ...; also with A as a center and same radius, as A0, describe the arc 0a; cutting A1 at a_1, and A2 at a_2, etc. Now, as the weights of the triangular prisms A01, A02, ... are proportional to 01, 02, ... (the bases of the triangles A01, A02, ... all of them having the same altitude), lay off on the vertical line on the left the distances 01, 02, 03, ... equal to the corresponding distances measured along the top slope of the earth. In the left figure draw 0a making the angle φ below the horizontal through 0. Next describe the arc ba with the radius A0, and lay off, with dividers, the chords aa_1, aa_2, aa_3, ... equal to the chords $0a_1$, $0a_2$, $0a_3$, ... of the right figure, and draw $0a_1$ $0a_2$, ... in the left figure. It is evident now that the lines 0a, $0a_1$, $0a_2$, ..., of the left figure, make the angle φ with the normals to the planes A0, A1, A2, respectively on the right, so that they may be taken to represent the direction of the R's (Fig. 1) corresponding to those planes.

Next, let us assume the direction of the thrust E on the wall to be parallel to the top surface of earth (this subject

will be considered more fully in the sequel), and draw the lines 11′, 22′, 33′, .. parallel to this top slope to intersection 1′, 2′, 3′, . . . with the lines $0a_1$, $0a_2$, $0a_3$, . . . then it follows that the lines 11′, 12′, 33′ . . . represent the thrusts on the wall E, due to the successive prisms A01, A02, A03, . . .; and by Coulomb's principle the greatest of these lines, 66′ gives the actual *active* thrust on the wall; which is thus caused by the prism A06, the plane A6 being the surface of rupture. The vertical tangent to the curve drawn through the points 1′2′3′ . . . , of course touches this curve at its greatest distance from the force line 0-10.

To get the thrust E in pounds, we have simply to multiply the length of 66′, to scale, by ½ the perpendicular drawn from A on 0-10 (top slope) produced, and this product by the weight in pounds of a cubic unit of earth.

It is evident that the construction is more accurate the greater the number of planes of rupture assumed, especially those near the true one. To test the stability of the wall it is by no means necessary to find E in pounds. See Eddy's *Researches in Graphical Statics* further, on this graphical treatment of the subject.

In case the passive resistance of the earth to sliding up some plane is required, we lay off the angle $boa=\varphi$ above *ob*, and then from the point *a* (above *b*) as before, lay off arcs $aa_1=0a_1$, $aa_2=0a_2$, . . . ; the construction is then proceeded with as before. Now, however, it is the least one of the resistances, 11′, 22′, 33′, etc., that represents the greatest force the earth can withstand without sliding up the inclined plane of rupture corresponding.

In the constructions just given, we have regarded E as variable, and ascertained its maximum value—the true one—as the planes of sliding were varied.

In the method followed by Weyrauch, E *is regarded as constant* and equal to the true thrust on the wall, and *the real surface of rupture is taken to be that plane for which the normal angle of* R *is the greatest consistent with equilibrium.*

This is in perfect agreement with Coulomb's principle, for note in Fig. 2, that if the lines 11′, 22′, . . . , be extended to the vertical through 6′, so that all the thrusts E are taken equal to 66′, the true one; these lines drawn from 0 to these intersections with the vertical, representing thus the *actual* values of R for any plane, will make less angles than φ with the normals to these planes, since these directions are nearer horizontal than before. It follows that it is only along A6, the true surface of rupture, that R=06′, makes the angle φ with its normal; in other words, that the normal angle of R is a maximum.

Let us now proceed to give Weyrauch's method of finding the thrust E, in magnitude, position and direction.

To take the most general case, let Fig. 3 represent the wall AB retaining the earth whose top surface BC has any given shape.

Call G the weight of the prism of earth ABC, P and Q are its components parallel and normal to the plane AC.

R is the resistance of the plane AC, P_2 and Q_2 being its components parallel and perpendicular to AC.

E represents the resistance offered by the wall AB, P_1 and Q_1 being its components parallel and perpendicular to AC.

AB makes the angle α with the vertical, AC the angle w. We do not as yet know the angle d, that E makes with the normal to AB, but it will be eventually determined from mechanical principles.

Now G is held in equilibrium by E and R, therefore, the sum of the components ∥ AC must equal zero,

$$\therefore P-P_1-P_2=o \ldots\ldots (1)$$

Also the sum of the components perpendicular to AC must be zero

$$\therefore Q+Q_1-Q_2=o \ldots\ldots (2)$$

The sum of the moments of the forces E, G, and R, about any point must likewise equal zero. Let A be taken as the centre of moments, and call the lever arms of the forces E, G, and R, e, g, and r respectively; we have,

$$Gg+Ee-Rr=o \ldots\ldots (3)$$

This equation (3) was first iutroduced by Weyrauch to determine d, and thus avoid *assuming* some value for it, supposed to be in accordance with the truth. We shall discuss its utility further on. There is no question as to its truth. Again, we must have always,

$$\frac{P_2}{Q_2} \leq \tan\varphi \therefore \frac{P-P_1}{Q+Q_1} \leq \tan\varphi \ldots\ldots (4)$$

We have just seen that it is only at *the surface of rupture* that R makes the angle φ with the normal to AC, *i.e.*, that

$$P-P_1=(Q+Q_1)\tan\varphi \quad . \quad . \quad . \quad . \quad (5)$$

The position of this plane of rupture is thus determined by making $\frac{P-P_1}{Q+Q_1}$ a *maximum*, consistently with equilibrium.

In order to find this position of AC, we place, as usual, the first differential coefficient equal to zero.

$$\therefore \frac{d\left(\frac{P-P_1}{Q+Q_1}\right)}{dw}=0 \quad . \quad . \quad . \quad . \quad (6)$$

It must be remembered that E is taken as constant and equal to the true earth pressure on the wall, whilst G and R and w, as well as AC$=k$ vary.

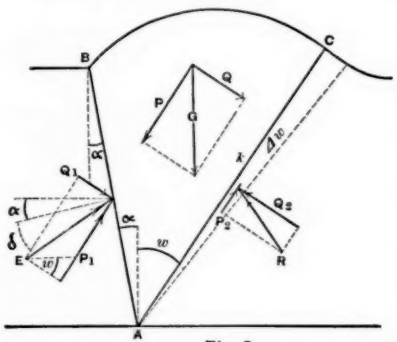

Fig. 3.

From Fig. 3 we readily find,

$$P=G\cos w,\ Q=G\sin w,$$
$$P_1=E\sin(w+a+d)$$
$$Q_1=E\cos(w+a+d)$$

For *the surface of rupture*, we have from (5),

$$G\cos w-E\sin(w+a+d)$$
$$=[G\sin w+E\cos(w+a+d)]\tan\varphi$$

whence,

$$E=\frac{\cos w-\sin w\tan\varphi}{\sin(w+a+d)+\cos(w+a+d)\tan\varphi}G$$

$$\therefore E=\frac{\cos(\varphi+w)}{\sin(\varphi+w+a+d)}G \quad . \quad . \quad . \quad . \quad (7)$$

This equation, it must be borne in mind, is true only for the surface of rupture. We have now from (6)

$$\frac{d}{dw}\left(\frac{G\cos w-E\sin(w+a+d)}{G\sin w+E\cos(w+a+d)}\right)=o$$

Performing the differentiation, remembering that G and w are the only variables, and putting the numerator equal to zero, since the denominator is finite, we have after simple reductions

$$-G^2+2GE\sin(a+d)$$
$$+E\cos(a+d)\frac{dG}{dw}-E^2=o$$

Calling γ the weight of a cubic unit of earth, the length AC being called k, we have nearly,

$$\Delta G=\tfrac{1}{2}k\Delta w.k\gamma$$

and exactly at the limit,

$$lim\frac{\Delta G}{\Delta w}=\frac{dG}{dw}=\tfrac{1}{2}k^2\gamma$$

Substituting in the preceding eq., we have,

$$\frac{G}{E}-2\sin(a+d)-\frac{k^2\gamma}{2G}\cos(a+d)+\frac{E}{G}=o$$
$$. \quad . \quad . \quad . \quad (8)$$

Substituting the values of $\frac{G}{E}$ and $\frac{E}{G}$ from (7) we find,

$$G=\frac{k^2\gamma}{2}\frac{\cos(a+d)\cos(\varphi+w)\sin(\varphi+w+a+d)}{D}$$

where,

$$D=\sin^2(\varphi+w+a+d)+\cos^2(\varphi+w)$$
$$-2\sin(a+d)\sin(\varphi+w+a+d)\cos(\varphi+w)$$

By successive trigonometrical reductions D becomes $\cos^2(a+d)$, whence we have for the weight of the *prism of rupture*,

$$G=\frac{\cos(\varphi+w)\sin(\varphi+w+a+d)}{\cos(a+d)}\cdot\frac{k^2\gamma}{2}$$
$$. \quad . \quad . \quad (9)$$

Substituting the value of $\sin(\varphi+w+a+d)$ drawn from (9) in eq. (7), we have,

$$E=\frac{\cos^2(\varphi+w)}{\cos(a+d)}\cdot\frac{k^2\gamma}{2} \quad . \quad . \quad . \quad . \quad (10)$$

We have also, since the sum of the horizontal components of E, G and R must be zero,

$$E\cos(a+d)=R\cos(w+\varphi)$$

whence,

$$R=\cos(\varphi+w)\frac{k^2\gamma}{2} \quad . \quad . \quad . \quad . \quad (11)$$

These equations 9, 10 and 11, still include w and d, as yet undetermined.

By the aid of Fig. 4, the values of G, E and R may be represented graphically. Thus, let AD be the natural slope, AC the surface of rupture, and CH a perpendicular let fall from C on AD. The angle ACH is thus equal to $w+\varphi$. Now draw CI making the angle HCI equal to $\alpha+d$ the angle of E with the horizontal, and draw $AN \perp CI$, then it follows that *the area of the triangle* ACI *is equal to the area* ABC *of the base of the prism of rupture.* This is made evident by writing (9) in the following form, remembering that $AC=k$:

$$G=\frac{\gamma}{2}.$$

$$k\cos(\varphi+w).k\sin(\varphi+w+\alpha+d).\sec(\alpha+d)$$

$$=\frac{\gamma}{2}\,CH.AN.\frac{CI}{CH}=\gamma.\frac{AN.CI}{2}.$$

Now lay off IL=IC and AM=AC, *then the product of* γ *by the area of the triangles,* CIL *and* ACM, *gives the pressures* E *and* R *respectively.*

Write 10 and 11 as follows:

$$E=\frac{\gamma}{2}.k\cos(\varphi+w).k\cos(\varphi+w)\sec(\alpha+d)$$

$$=\frac{\gamma}{2}CH.CI=\gamma.\frac{CH.IL}{2}.$$

$$R=k\cos(\varphi+w)\frac{k}{2}\gamma=CH\frac{k}{2}\gamma$$

$$=\gamma.\frac{CH.AM}{2}.$$

We have thus shown that

$$G=\gamma.\Delta ACI$$
$$E=\gamma.\Delta LCI$$
$$R=\gamma.\Delta ACM$$

the symbol Δ here denoting "area of triangle."

Rebhahn, in 1871, found the first two

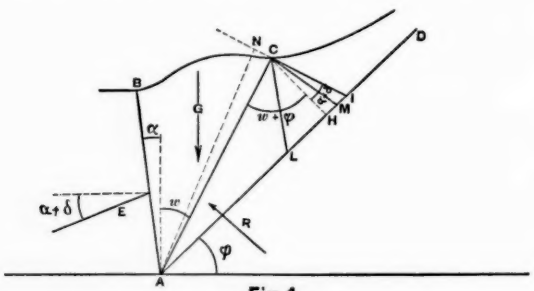

Fig. 4.

of the above relations, assuming, however, that $d=o$ or $d=\varphi$. The third relation is new and due to Weyrauch.

We can state these relations also in the form of a proportion,

$$G : E : R :: AI : IC : AC \quad \ldots . \quad (12)$$

Or G, E and R are as the sides of the triangle ACI.

The above relations have been established irrespective of any particular values of d, and irrespective of the character of the curve BC of the surface of the ground.

We cannot proceed further with this general solution, but must now consider *the earth surface as sloping at some angle,* ε *to the horizontal.*

From Fig. 5, we note the following relations of the angles:

$$BAC=\alpha+w$$
$$ACB=90-(w+\varepsilon)$$
$$ABC=90-(\alpha-\varepsilon)$$
$$CAD=90-(w+\varphi)$$
$$ACI=w+\varphi+\alpha+d$$
$$ADC=\varphi-\varepsilon$$

Now since, $\Delta ABC=\Delta ACI$,

$$AB.AC\sin BAC=AI.AC\sin CAI.$$

$$\therefore \frac{AB}{AC}.\sin BAC=\frac{AI}{AC}\sin CAI$$

whence,

$$\frac{\sin ACB.\sin BAC}{\sin ABC}=\frac{\sin ACI.\sin CAI}{\sin AIC}$$

$$\therefore \sin(\alpha+w)\cos(\varepsilon+w)\cos(\alpha+d)=$$
$$\sin(\varphi+w+\alpha+d)\cos(\varphi+w)\cos(\alpha-\varepsilon)$$
$$\ldots\ldots \quad (13)$$

Draw $BN \perp BD$.

Now $\Delta ABD=2\Delta AIC+\Delta IDC$

$$\therefore AD.BN=2AI.CH+ID.CH.$$

Now drawing BO ‖ CI making angle NBO=$a+d$,

$$\frac{BN}{CH}=\frac{BO}{CI}=\frac{OD}{ID};$$

whence dividing the previous equation by CH, and reducing by these relations, we have,

$$AD.OD=ID(AI+AD).$$
$$\therefore AD(AD-AO)=(AD-AI)(AI+AD)$$
$$\therefore AO.AD=\overline{AI}^2 \quad . \quad . \quad . \quad . \quad (14)$$

Therefore AI is a mean proportional between AO and AD. So that to find the surface of rupture, when d is known, we draw BO, making the angle $a+d$ with the normal to the natural slope; then we lay off $AI=\sqrt{AO.AD}$, and from I draw the line IC ‖ OB to C; whence AC is the surface of rupture, and the angle w is determined. On multiplying γ by the area of the triangle ICL or by substituting the values of w and d in eq. 10, we have the value of E.

AI may be determined graphically by describing a semi-circle on AD, and drawing a line ⊥ AD at O to the curve. This line is, of course, a mean proportional between AO and AD, and is therefore equal to the required line AI.

We shall now proceed to frame a formula for E in which the angle w does not appear. We have

$$E=\gamma.\Delta CIL=\tfrac{1}{2}\gamma.\overline{IC}^2\cos(a+d)$$

$$\frac{CI}{BO}=\frac{AD-AI}{AD-AO}$$

$$=\frac{AD-\sqrt{AD.AO}}{AD-AO}=\frac{1-\sqrt{\frac{AO}{AD}}}{1-\frac{AO}{AD}}$$

Placing $n=\sqrt{\frac{AO}{AD}}$, we have

$$CI=\frac{1-n}{1-n^2}BO=\frac{BO}{1+n}$$

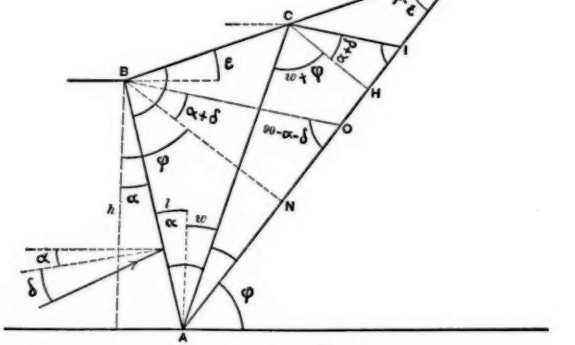

Fig. 5.

In Fig. 5, angle $ABO=\varphi-a+a+d=\varphi+d$, whence,

$$\frac{AO}{AB}=\frac{\sin(\varphi+d)}{\cos(a+d)},\quad \frac{AB}{AD}=\frac{\sin(\varphi-\varepsilon)}{\cos(a-\varepsilon)}$$

Multiplying these two equations together, and extracting the square root, we find,

$$n=\sqrt{\frac{\sin(\varphi+d)\sin(\varphi-\varepsilon)}{\cos(a+d)\cos(a-\varepsilon)}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Put $AB=l$, then since

$BAO=90-(w+\varphi)+a+w=90-(\varphi-d)$

$$BO=\frac{\cos(\varphi-a)}{\cos(a+d)}l$$

Substituting these values of BO and n in that for CI, and this in value for E,

$$E=\left(\frac{\cos(\varphi-a)}{n+1}\right)^2\frac{l^2\gamma}{2\cos(a+d)} \quad . \quad . \quad . \quad . \quad (16)$$

Or calling the height of B above A, $h=l\cos a$,

$$E=\left(\frac{\cos(\varphi-a)}{(n+1)\cos a}\right)^2\frac{h^2\gamma}{2\cos(a+d)}\quad\ldots\ldots\ (17)$$

It is to be observed that when $\varepsilon=\varphi$, $n=o$, which simplifies the formulæ very much for this case. *In the case of liquids*, we have,

$\varphi=o$, $\varepsilon=o$, $d=o$, $n=o$, and $E=\frac{1}{2}h^2\gamma\sec.a$,

a well known formula.

We are now going to determine the angle d for earth pressure. Prof. Weyrauch does this by the use of eq. (3), which we have not used as yet. The following is a quotation from his article before referred to.

"In order to express e and r in eq. (3), the points of application of E and R must be known. The angles d and w can be determined the one from the other by means of (13). Now since d is independent of the depth, this is also true of w; therefore, regarding h as variable, from (16) and (11), we can write,

$$E=Cl^2 \qquad R=C_1k^2$$
$$dE=2Cldl, \qquad dR=2C_1kdk;$$

and we obtain the distances x, z, of the points of application from A, from the eqs.

$$E(l-x)=2C\int_o^l l^2dl\ \therefore\ x=\frac{l}{3}$$

$$R(k-z)=2C_1\int_o^k k^2dk\ \therefore\ z=\frac{k}{3}$$

whence,

$$e=\frac{l}{3}\cos d,\ r=\frac{k}{3}\cos\varphi$$
$$g=\frac{k}{3}\sin w-\frac{l}{3}\sin a"$$

By substituting these values, &c., Prof. Weyrauch deduces a complicated equation, which with the aid of (13) suffices to determine d.

The reductions required, even for the simplest cases, $\varepsilon=o$ and $\varepsilon=\varphi$ (it was not attempted for any other values of ε), are long and tedious in the extreme; but fortunately they can all be avoided by some simple considerations, for which, as well as for the remainder of this article, the writer must alone be held responsible.

But first, let us inquire more particularly into the method used above for finding e and r. Refer to Fig. 6, where AC is the plane of rupture, 13 ‖ 24 ‖ AC, and ab ‖ a_1b_1 ‖ AB. Now by our theory the thrust on the part $\overline{B1}$ of the wall is $C.\overline{B1}^2$, that on B2, is $C.\overline{B2}^2$, so that the actual thrust on the part 12 is

$$C(\overline{B2}^2-\overline{B1}^2)=\Delta E,$$

whence the value of dE, &c., is correctly found as above; so that *when the earth surface is plane, the thrust* E *always acts on* AB *at* $\frac{1}{3}$ AB *above* A.

The same method applies in finding the position of R, provided the *actual* thrusts on the the planes Ca and Ca_1 are due to the prisms Cab and Ca_1b_1 respectively. To prove that this is so, we

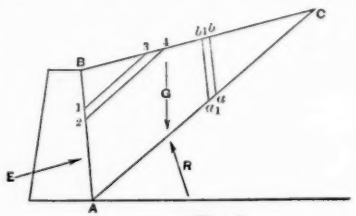

Fig. 6.

observe that the thrust on any plane ab parallel to AB, must have a direction parallel to E, since the same considerations determine its direction for plane ab as for plane AB. Therefore the direction of the thrust on Ca will be parallel to R, thus making the angle φ with the normal to AC; so that the prism Cab will be just on the point of sliding. Now, as this is as it should be, since AC is the plane of rupture, it follows that the *actual* thrust on Ca is given by the prism Cab; so that the thrust on the part aa_1 is the difference of the thrusts due to the two prisms Cab and Ca_1b_1, and of course acts parallel to R. It easily follows that R is applied at a point on AC, at a distance $\frac{1}{3}$ AC from A.

Now consider Fig. 7, in which G, the weight of the prism of rupture BCA, is decomposed by a vertical plane AD into two weights, W=weight of BAD and W′=weight of DAC. Since W and W′ act at the centers of gravity of the triangles ABD and DAC, their directions must intersect AB and AC respectively at the points of application of E and R, *i.e.*, one third of the distances AB and AC from A along the planes AB and AC

respectively. *It follows that* F, *the resultant of* W′ *and* R *must be parallel to the upper surface* BC, *and act at* $\frac{1}{3}$ AD *above* A.

On combining F with W we, of course, find E. Now since W is constant for any assumed position of BA, we see, that E is a maximum when F is a maximum. But F is a maximum when DAC is the prism of rupture for the plane AD, according to Coulomb's principle; therefore the plane of rupture AC for plane AD is also the plane of rupture for the plane or wall AB; *hence a simple method of procedure for finding* E, *when the top surface slopes uniformly, is to find the thrust on a vertical plane* AD *through* A, *which thrust acts parallel to the top slope and at* $\frac{1}{3}$ AD *above* A, *and afterwards combine this thrust with the weight of the prism of earth* ABD *which gives the resultant* E *required.*

It is needless then to encumber our formulæ for this case by inserting the angle α, since E can be so quickly found when F is known.

It follows from what we have said, that when F acts parallel to the top slope, the surface of rupture, AC, is independent of the inclination of AB. The case is different when we have to assume some direction to E, from physical considerations, as we shall see further on.

The fact that the thrust on a vertical plane, as AD, is parallel to the top surface is proved by Rankine in the following manner, in the case of a mass of earth extended laterally and downwards indefinitely. In Fig. 7 consider the element e, bounded by planes vertical and planes parallel to the top slope. *If the mass is exposed to no external force but its own weight,* the only pressure which any portion of a plane $mn \parallel$ DC can have to sustain, is the weight of the material directly above it, so that the pressure on the plane mn is everywhere uniform and vertical. The pressures on the upper and lower surfaces of the particle e, are thus vertical and their difference is equal, and opposite to, and balanced by, the weight of the particle. It follows that the pressures on the opposite vertical faces of the particle must balance each other independently, which can only happen when they act parallel to the top surface, in which case only they are directly opposed. It follows too, that the intensity of pressure at the same depth is everywhere the same, as we have previously seen to be true.

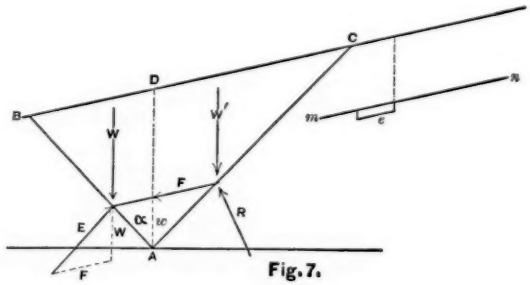

Fig. 7.

By different methods of reasoning we have thus reached the same conclusions, which are all true therefore, unless the wall AB introduces some modifying influences—some "external force" not considered above.

Since we have proved, that unless the wall causes modifying influences, that the thrust on a vertical plane is parallel to the top slope, we have from eq. (16), when $a=o, d=\varepsilon$ and $l=x=$AD (of Fig. 7), this earth thrust on AD (Fig. 7),

$$\mathrm{E}=\left(\frac{\cos\varphi}{n+1}\right)^2\frac{x^2\gamma}{2\cos\varepsilon}.$$

Also,

$$n=\sqrt{\frac{\sin(\varphi+\varepsilon)\sin(\varphi-\varepsilon)}{\cos^2\varepsilon}}$$

$$=\frac{1}{\cos\varepsilon}\sqrt{\sin^2\varphi\cos^2\varepsilon-\cos^2\varphi\sin^2\varepsilon}$$

$$\therefore\ n=\frac{\sqrt{\cos^2\varepsilon-\cos^2\varphi}}{\cos\varepsilon}$$

and,

$$E=\frac{\cos^2\varphi}{(\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi})^2}\cdot\frac{x^2\gamma}{2}\cos\varepsilon$$

Now since,

$$\cos^2\varphi=(\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi})(\cos\varepsilon-\sqrt{\cos^2\varepsilon-\cos^2\varphi})$$

we have, on dividing the numerator and denominator of E by

$$(\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi}),$$

$$E=\frac{\gamma x^2}{2}\cos\varepsilon\frac{\cos\varepsilon-\sqrt{\cos^2\varepsilon-\cos^2\varphi}}{\cos\varepsilon+\sqrt{\cos^2\varepsilon-\cos^2\varphi}} \quad . \quad . \quad . \quad . \quad (18)$$

which is Rankine's well known formula for earth pressure.

Now since Rankine's formula was framed without the use of any assumption, as that of a *plane* of rupture, and is accepted as correct, it must follow that the supposition that the surface of rupture is a plane, when the top surface is a uniform slope and the wall does not produce any external force, must be correct.

We are therefore safe in saying that it is, at least approximately correct, in other cases; so that the graphical treatment founded on this supposition may be relied on as giving good results. Rankine has given in his *Engineering* a very pretty graphical construction of the last fraction in eq. (18), that saves labor in computing.

When the top surface is level, $\varepsilon=o$, and we have,

$$E=\frac{\gamma x^2}{2}\frac{1-\sin\varphi}{1+\sin\varphi}=\frac{\gamma x^2}{2}\tan^2\left(45^\circ-\frac{\varphi}{2}\right) \quad . \quad . \quad . \quad . \quad (19)$$

When the surface slopes at the angle of repose, $\varepsilon=\varphi$.

$$E=\frac{\gamma x^2}{2}\cos\varphi \quad . \quad . \quad . \quad . \quad (20)$$

The pressure E in all cases acts parallel to the top slope and at a height $\frac{1}{3}x$ above A.

On combining these values of E with the weight W of the prism ABD (Fig. 7) we find the values for the pressure on the wall AB given by Weyrauch for the two cases $\varepsilon=o$ and $\varepsilon=\varphi$. Similarily his values for $\tan(a+d)$ are readily found. There seems to be no advantage to be derived from deducing these values, since the weight of the wall and of the prism ADB can be taken together as acting at their common center of gravity, in testing the wall, either as to its stability against overturning, or as regards sliding on its base. Besides, it is simpler to have one formula (18) that solves every case, and that can moreover be easily remembered.

We have hitherto supposed that the wall was immovable, so that the pressure upon it would be the same as upon a section AB in an indefinitely extended mass of earth; besides it has been tacitly assumed that the friction between the wall and the earth was at least equal to that between earth and earth.

The case is different if the wall is just on the point of overturning, or sliding on its base, for now the friction between the earth and wall causes E to make an angle φ with the normal to the wall. *Now if the surface of rupture* AC *for this case is supposed to be plane,* as before, then R cannot act at $\frac{1}{3}$ AC from A, if E makes an angle with the normal to AB greater than results from previous considerations; hence, *thrusts on planes ab* (Fig. 6) *are no longer parallel to* E, otherwise we should undoubtedly deduce, as previously shown, that R acts at $\frac{1}{3}$ AC from A; whereas it is plain that it must act above its present position. This is as we should expect, for it is only at the wall AB that the greatest movement and friction occurs to alter the *usual* direction of the thrust in a mass of earth of indefinite extent, which we have shown to be parallel to the top surface of the earth, when taken on a vertical plane, perpendicular to the plane of the section.

Similarly if the angle of friction between the wall and earth is less than *d*, as determined above, then E must be regarded as making this angle of friction with the normal to the wall.

It is plain now that R acts nearer A than $\frac{1}{3}$ AC. If the wall is regarded as *perfectly smooth,* so that E is nearly horizontal, then R acts nearer A than on any other supposition. In all these cases, as we go from the wall, the direction of the thrust on planes such as *ab* (Fig. 6) is constantly changing until the usual direction of this thrust is attained.

It is evident that eq. (3) can be of no use in these cases, since *r* cannot be determined. *However, having assumed d in accordance with the facts of the case,*

the thrust E *at once follows from eqs.* (16) *and* (17). The thrust E of course acts on AB at $\frac{1}{3}$ AB from A.

It has been the fashion with many recent writers on this subject to *assume* $d=\varphi$ in every case. Now it is evident that for values of ε less than φ the full friction between the earth and wall cannot be exerted except when motion is about to begin. Thus, in experiments with models, this supposition $d=\varphi$ agrees (as far as I know) with actual results better than any other, when coupled with a *rational* theory. But if the wall has a large excess of stability any motion forward will be slight. In fact, if the wall is given such a shape that the final resultant on its base passes through its center, then there can be no motion forward at all, and hence no friction at the wall over that found before. If, however, this resultant passes near the outer edge there will be slight forward motion, even with a firm rock foundation, and considerable forward rotation if the foundation is not practically incompressible. Again, it may be that the settling of the earth, after it is deposited, may cause considerable friction at the back of the wall, which, however, may be gradually destroyed by vibrations, rains, etc.

Admitting, then, that this settlement of the wall and earth cause a certain amount of indetermination as regards the direction of the thrust E, it is certainly well in a practical point of view to take the most unfavorable case in *designing a wall; in other words, use eq.* (18), *regarding* E *as acting parallel to the top slope, since this gives a greater thrust than when* E *is given a direction nearer the vertical*, as we see plainly from Fig. 2. Weyrauch urges the following objections to taking $d=\varphi$ in all cases: take a tunnel arch, and if we suppose the pressure, as we go up from either side, to make always the angle φ with the normal, we shall have at the crown two differently directed pressures, both making an angle φ with the vertical normal, but on opposite sides. Or take a horizontal wall with level topped earth resting on it. The pressure, of course, should be vertical. These objections are sound if no motion occurs, but if the tunnel arch or horizontal wall are just on the point of moving then, as in the case of the retaining wall, just at the limit of stability, there is friction exerted in a certain direction so that the thrust can have but *one* direction making the angle φ with the normal; in fact, Weyrauch admits as much himself, where *sliding* of the wall on its base occurs; and it is difficult to see how it can be otherwise in the case of a wall just at the limit of stability. It may be observed here that in experiments on models the earth should not be confined in a box, for as the wall gives there is friction exerted between the sides of the box and the prism of rupture as it moves downwards. It seems best to adopt Trautwine's method of having the earth unconfined, the wall tapering at its ends with the side slopes of the earth, its thickness likewise diminishing to nothing as the bottom of the slope is reached. The wall should be as long as convenient in order to eliminate the error due to the unknown thrusts from the side slopes as much as possible.

In cases where the earth behind a retaining wall is loaded uniformly, we find the additional height, x_0 of earth required to have the same weight, and estimate the earth thrust on a vertical plane, for the depth x_0, as well as for the depth, $H=x+x_0$, x being the original depth of earth. Their difference gives the earth thrust on the original plane whose height is x.

The point of application of this thrust (which may be represented graphically by a trapezoid) is at a height above the lowest point,

$$y=\tfrac{1}{3}\frac{H^3-x_0^3}{H^2-x_0^2}.$$

Referring once more to eq. 17, we see that for the theoretical case of a vertical wall, *perfectly smooth*, the surface earth sloping at the angle of repose, for which $d=o$, $\varepsilon=\varphi$ and $\alpha=o$, that $n=o$, and,

$$E=\frac{h^2\gamma}{2}\cos^2\varphi$$

This value is the horizontal component of the value of E given by eq. (20), where the wall is supposed to be capable of affording the friction with the earth, whose coefficient is *tan* φ.

This value is found likewise directly from eq. (7) on substituting for G its value for this case,

$$G=\frac{\gamma h^2}{2}\frac{1}{\cot w-\tan\varphi}=\frac{\sin w\cos\varphi}{\cos(w+\varphi)}\frac{\gamma h^2}{2}$$

We have now from (7), on making $a=o$, $d=o$

$$E=\frac{\cos(\varphi+w)}{\sin(\varphi+w)}\frac{\sin w\cos\varphi}{\cos(w+\varphi)}\frac{\gamma h^2}{2}$$

$$=\frac{\gamma h^2}{2}\frac{1}{1+\tan\varphi\cot w}$$

Now by Coulomb's principle this value of E is to be a maximum. The only variable in the right member being $\cot w$, which is smaller as w is greater, we evidently make E a max. by giving w its greatest value $(90-\varphi)$, in which case the surface of rupture coincides with the line of natural slope through the foot of the wall—its *limiting position*. E now becomes

$$\frac{\gamma h^2}{2}\frac{1}{1+\tan^2\varphi}=\frac{\gamma h^2}{2}\cos^2\varphi,$$

the value before found. It will be observed that this result is reached without the aid of the calculus.

The same style of demonstration applies in deducing eq. (20) without the aid of the calculus.

We have now in eq. (7), $a=o$, $d=\varphi$, and the value of G as given above,

$$\therefore E=\frac{\sin w\cos\varphi}{\sin(2\varphi+w)}\frac{\gamma h^2}{2}=$$

$$\frac{\cos\varphi}{\sin 2\varphi\cot w+\cos 2\varphi}\frac{\gamma h^2}{2}$$

which is a max., as before, for $w=90-\varphi$. Whence, at the limit,

$$E=\frac{\gamma h^2}{2}\cos\varphi$$

The surface of rupture in this case coincides with the line of natural slope. Eq. (7) in this case assumes the form, $o\times\infty$, since G becomes infinite for an indefinitely sloping surface; but on reducing to the form above, we easily see the limit that E approaches but cannot exceed, which is its true value.

By reference to eq. (19), it is seen that for the case of a *level topped bank* that, $w=45°-\frac{\varphi}{2}$, or $2w=90-\varphi$, since this value alone will give (19). *For level topped earth then, the line of rupture bisects the angle between the vertical and the line of natural slope.*

In the case of a liquid, $\varphi=o$, whence w makes an angle of 45° with the vertical.

It is not proposed in this paper to frame equations by which to compute the thickness of retaining walls, since this part of the subject has been fully discussed by Rankine and others. Suffice it to say that on combining the earth thrust on a vertical plane through the inner foot of the wall with the weight of earth and wall in front of it acting at their common center of gravity, that we find, by a graphical construction, the point where the resultant strikes the base of the retaining wall and its inclination to the normal to that base. If the latter is less than the angle of friction between this base and the foundation, then the wall will *slide* outwards, and either the base must be inclined more to the horizontal, or this friction must be increased in some way as by imbedding stones in the foundation surface, or if it is of timber, by allowing beams to project above its surface, etc.

It will be found that for walls having a considerable batter, or with counterforts, that sliding is more to be feared than overturning when the foundation is of wet clay or timber, the co-efficients of friction for these cases ranging as low as .33 to .4, whilst for rock it averages two-thirds.

To insure a proper excess of stability against overturning, Rankine says that English and French engineers allow the resultant to approach no nearer the outer edge than from $\frac{1}{8}$ to $\frac{1}{5}$ of the width of base.

However this may be, it is certain that if we regard the wall as made up of blocks resting on each other, and extending the entire width of the wall, that if the resultant on any block falls without the middle third of the joint, that the joints will open along their inner edges, thus allowing the infiltration of water. Stability is, of course, assured against overturning when the resultant strikes anywhere within the base, provided crushing of the outer toe is not to be feared; and this holds generally when the resultant is limited to an extreme approach to this toe of $\frac{1}{8}$ to $\frac{1}{5}$, the diameter of base; but it seems to me that this limit introduces too small "a factor of safety," considering that rains may saturate the ground, and not only increase the specific gravity of the mass pressing against the wall but lessen its friction,

not to speak of the effects of this water when freezing and expanding.

To use every precaution, gravel or dry rubble should be put next the wall for a foot in thickness, say, and weeping holes and drains must be provided along the foot of the wall to pass off the water. In dock walls the earth is often saturated with water unless a puddle wall is built next the retaining wall.

Again, in all cases where loads pass over the earth, accompanied by jars, the pressure against the wall is increased, so that when all the influences are considered that we have enumerated, it would seem that Rankine's factor of safety is certainly the minimum one.

It should be remembered that whenever the resultant lies near the outer toe that there will be greater compression caused there than at the inner toe, so that the wall will *lean* slightly forwards, thus moving the center of gravity of the wall slightly forwards. This slight forward movement, though, causes friction between the earth and wall, which may help to counteract its bad effects.

Often the relative specific gravity of the masonry to the earth is taken too high.

It would seem *safe* to assume the weight per cubic foot of settled earth to vary from 120 to 130 lbs., of brickwork 110 lbs., of sandstone masonry 130 lbs., and of granite masonry 142 lbs.—the walls consisting of one-half ashlar and one-half rubble backing. The value of φ may be taken at 34°. We have hitherto considered the case where the wall A B makes an angle α to left of the vertical. When the wall leans to the right of the vertical, or backwards, the case is as given by Rankine in his *Civil Engineering*, unless we have to assume some value of d (when wall is at or near the limit of stability) not in agreement with Rankine's determination, in which case α becomes negative in formulae (15) and (16), and the value of E is found from them, after substituting the assumed value of d.

A strict solution of the case where *the earth surface is of irregular shape* seems impossible; for now it cannot be proved that the direction of the earth thrust at different depths is the same, so that this direction remains indeterminate (unless the wall is at the limit of stability, when it will be inclined at the angle φ to the normal to the *rough* wall); besides, since the pressure cannot be shown to increase uniformly as we go downwards, the position of the resultant earth thrust is indeterminate. We can say generally that this position for surcharged revetments is somewhere between $\frac{1}{3}\ h$ and $\frac{1}{2}\ h$ above the base of the wall. It can never reach the latter value, which corresponds to a uniformly distributed thrust, and it most likely never exceeds $\frac{4}{10}\ h$; still any attempt to locate this resultant exactly is only guess work. Lastly, the surface of rupture is most probably no longer a plane, though we have to assume that it is.

An approximate solution of this case can best be made by a graphical analysis similar to that given in Fig. 2. The only difference being that the triangles forming the bases of the successive prisms of rupture must each be reduced to equivalent triangles having the same altitude, so that their bases can then be laid off on the load line representing the forces G. This is easily done by the usual geometrical method of forming equivalent triangles having the same base and altitude. Next, an approximation for a stable wall the direction of the thrust may be assumed as a rough mean of the inclinations of the upper surface of the probable prism of rupture, and this prism then determined by construction. It is plain that if the earth thrust is taken perpendicular to the wall, that it will be a maximum, and therefore the assumption is a safe one.

In conclusion, the writer is aware that in opening the discussion of earth thrust again, it would seem that some apology was needed, except that the aim has been rather to reconcile conflicting theories where possible, and show their common points than to advance any perfectly novel theory of his own. Irrational theories are still being presented, and it is necessary to guard against them by bearing well in mind what has been established as true and what as false, and more especially by a consideration of the subject in its most comprehensive aspect.

COMPOUND ARMOR

From "Iron."

The battle of Guns *versus* armor has been fought—and well fought, too—for many years past. At one time it has been the guns that have had the best of it, whilst at another the plates have baffled the guns. No sooner has this latter condition obtained than the guns have been increased in size and power, until at last they would seem to have been left masters of the situation. This being the case, another effort to turn the tables upon the guns has been made, this time not by increasing the thickness of the iron plates, which had already about reached the limits of safety as regards the ship, nor by making them of steel, which is not adapted to resist every kind of artillery fire, but by effecting a compromise, and using both these metals in conjunction. The precise value of steel, as a material for armor plates, was established by the artillery experiments which were carried out in the autumn of 1876 at Spezzia. There both wrought iron and steel plates were tried by both light and heavy artillery. The results showed that whilst 10-inch projectiles penetrated from 10 to 13 inches into the solid iron plates, the steel plates, though not penetrated were so starred and split by the racking to which they had been subjected that they threatened to fall to pieces. But whilst the steel plates were unable to withstand a continuous fire from even comparatively light ordnance, they nevertheless resisted the punching energy of the 100-ton gun, though shivering under blows which easily penetrated the iron armor. The inference drawn from these and other circumstances was that steel was well calculated to enable a vessel to bear a single blow of a projectile from a gun of superior power to its armor; while, on the other hand, such plating must be expected to crumble under the continuous fire of guns which could not easily injure wrought-iron armor of the same thickness.

The question arising upon this was how the special qualities both of the iron and the steel might best be turned to advantage in keeping out the projectiles. In other words, the manufacturers of armor-plates had to discover the means of producing plates which should be proof against both the punching and the racking effects of artillery fire. For the successful solution of this problem the country is indebted to our two great armor-plate makers, Messrs. John Brown & Co., of Sheffield, under their chairman's—Mr. Ellis—patent, and Messrs. Cammell & Co., also of Sheffield, under Mr. Alexander Wilson's patent. The way in which they solved the question was to effect a perfect union of the two metals and to produce a compound plate, that is, a plate having a steel face and an iron backing. Here the steel does its work in preventing penetration by causing the shot to break up on impact, whilst the iron performs its part in preventing the destruction of the steel by reason of its greater tenacity and ductility. We need hardly say that the two metals had previously been successfully welded together for use in railway practice, but the conditions in artillery practice were so widely different that, plates simply welded together were found to separate very soon under fire in the early experiments with compound plates. The method by which these plates are now produced by the firms we have mentioned consists in pouring the liquid steel upon the heated iron plate, the details of the process, however, differing in each case. In this process the temperature of the molten steel being in excess of the welding heat of the iron, the surface of the heated iron plate becomes partially fused by the liquid steel, and thus a complete union or weld between the two metals is obtained. In this case the weld is not confined to a simple line marking the difference between the steel and the iron, as in ordinary welds, but a third metal or semi-steel is formed between the two, varying in thickness from $\frac{1}{8}$ inch to 3-16 inch, by the carbon of the steel running into the iron. Through the formation of this zone of anomalous steel the two metals are joined together inseparably; or, in other words, the steel has gradually run into the fibrous iron and the iron into the steel. Experiments have been made to ascertain the relative strength of the weld thus produced, and on every oc-

casion the iron only has been torn asunder, while the weld itself remained undisturbed.

The experience thus gained led the constructive department of the Admiralty to direct that the turrets of the *Inflexible* should be plated with compound armor, which, as a matter of fact, is now in course of being done. The testing of the plates for this vessel, in conjunction with the results of the previous experiments, so satisfied the Admiralty as to the superiority of steel-faced plates over every other description of armor, that they have finally adopted it as a means of defence for our future ships of war.

THE ABSOLUTE ZERO OF TEMPERATURE.

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Contributed to VAN NOSTRAND'S ENGINEERING MAGAZINE.

IN the February number of this Magazine Professor Wood has called attention to an erroneous article on the above subject in the November issue, taken from the *Revue Industrielle*. We wish Professor Wood had gone further, and not only pointed out that the formula for the volume of a gas which was then deduced did not accord with experiment, but had also pointed out the two very common errors on which the formula was based. The first of these two errors consists in supposing that the absolute zero of temperature depended upon and could only be determined from the coefficient of dilation of a perfect gas, and that since there are no perfect gases there must be as many absolute zeros as there are gases or coefficients of dilation.

The second error consists in misunderstanding what is meant by the coefficient of dilation.

We believe that the first of these errors can be best met, and *absolute* temperature best explained, by stating the meaning and origin of this term without attempting to give its physical interpretation, for we thus avoid all hypothesis as to the nature of heat and all speculations as to what possibly might take place if the absolute zero could be reached.

The absolute scale of temperature is due to W. Thomson, who pointed out that "any system of thermometry, founded either on equal additions of heat, or equal expansions, or equal augmentations of pressure, must depend upon the particular thermometric substance chosen, since the specific heats, the expansions and the elasticities of substances vary, and, so far as we know, not proportionally with absolute rigor for any two substances. Even the air thermometer does not afford a *perfect standard*, unless the precise constitution and physical state of the gas used (the density for a pressure thermometer, or the pressure for an expansion thermometer) be prescribed. It appears then that the standard of practical thermometry consists essentially in the reference to a certain numerically expressed quality of a particular substance." The question "Is there any principle on which an absolute thermometric scale can be founded?" is raised by Thomson, and then answered, "by showing that Carnot's function (derivable from the properties of any substance whatever, but the same for all bodies at the same temperature) or any arbitrary function of Carnot's function may be defined as temperature, and is therefore the foundation of an absolute system of thermometry."

That Carnot's function is simply and solely a function of temperature follows directly from the well-known proposition: The efficiency of any theoretically perfect engine is independent of the substance employed in driving it, and is simply a function of the two limits of temperature betweeen which the engine works. For if we write the expression for the efficiency for the particular case, in which the perfect engines have the infinitely small range of temperature dt, namely:

$$\text{Efficiency} = \frac{\left(\frac{dp}{dt}\right)_v}{J\left(\frac{dQ}{dv}\right)_t} dt,$$

J being the numerical constant known as Joule's equivalent $\left(\frac{dp}{dt}\right)_v$ the rate at which the pressure varies with the temperature when the volume remains con-

stant, and $\left(\frac{dQ}{dv}\right)_t$ the rate at which the heat, furnished to or abstracted from the body, varies with the volume when the temperature remains constant, we will readily see that $\left(\frac{dp}{dt}\right)_v \div \left(\frac{dQ}{dv}\right)_t$ is the only variable factor in the expression for the efficiency, and that consequently this factor must be a function of the only quality—temperature—with which (as the above proposition informs us) the efficiency varies. This factor $\left(\frac{dp}{dt}\right)_v \div \left(\frac{dQ}{dv}\right)_t$ is Carnot's function, its reciprocal multiplied by Joule's equivalent J, is what Thomson took for the foundation of his absolute system of thermometry.

The numerical values of this function for any given temperature, such as the freezing point of water, can be determined for any one of a series of bodies of the most widely different properties, provided only that the bodies are all at the given temperature, and that the relations between the pressure, volume and temperature of each body, near the given temperature are known. It is because of this last condition that the numerical determinations* have been principally and best made on such simple, well-known bodies as gases and vapors. The values obtained differ more or less, but the best of them is believed by Thomson to be very near the true value.

The numerical values of Carnot's function having been once accurately ascertained, the arbitrary function of it which is to form the basis of the scale of absolute temperature, can also be calculated. It is of course desirable that the form of this arbitrary function be such as to facilitate reductions from the absolute scale to the scale of the standard air thermometer in which the past observations of temperature have been expressed. This fortunately can be most easily done with sufficient accuracy for most practical purposes, for Thomson found that the numerical values of Carnot's function, which he had obtained for different temperatures, varies very nearly inversely as the readings of a standard air thermometer, whose freezing and boiling points were respectively marked 273.7° and 373.7°. The reciprocal of Carnot's function multiplied by the numerical constant known as Joule's equivalent was, therefore, assumed by Thomson as the basis of an absolute system of thermometry. The numerical value T of temperature expressed absolutely may therefore be obtained from the equation

$$T = J \frac{1}{\left(\frac{dp}{dt}\right)_v \div \left(\frac{dQ}{dv}\right)_t}$$

The best empirical formula which has thus far been deduced for the relation between the absolute temperature T and the readings t of a standard air thermometer of constant volume, of which the freezing and boiling points are respectively marked 0° and 100°, is as follows:

$$T = 273.89 + 1.00026\, t - 0.0000026\, t^2$$

when $t=0$ $T=273.89$,

which is probably correct within a small fraction of a degree.

The second error above mentioned consists in assuming the co-efficient of dilatation a, used in the general formula $pv = c\,(1 + a\,t)$ for gases nearly perfect, to be the ratio of the increment of volume for one degree rise in temperature (the pressure being constant) to the volume which existed at the beginning of the rise of temperature. This can, perhaps, be more clearly expressed by the aid of symbols.

Let v_0 = vol. of gas for temp. $t=0$
v = " " " " t
v_1 = " " " " $t+1$

then the error above mentioned consists in assuming

$$a = \frac{v_1 - v}{v} = \text{constant.}$$

The correct expression would be

$$a = \frac{v_1 - v}{v_0} = \text{constant.}$$

It is this last value which is constant throughout the ordinary range of temperature, and from which the formula

$$v = v_0\,(1 \times a\,t)$$

can be obtained which accords with experiment. On the other hand, the first and erroneous assumption gives the incorrect and misleading formula

$$v = v_0\,(1 + a)^t$$

* See Clapeyron, *Journal de l'école Polytechnique* (1834), vol. XIV, p. 170, and *Pogg. Ann.*, vol. XLIX, p. 446. Thomson, "On an Absolute Thermometric Scale," founded on Carnot's theory of the motive power of heat, and calculated from Regnault's "Observations on Steam," *Proc. Camb. Phil. Soc.*, June 5, 1848, and *Phil. Mag.*, Oct., 1848; also, Thomson and Joule, "On the Thermal Effects of Fluids in Motion," Sec. III, "Evolution of Carnot's Function," *Phil. Trans.*, vol. CXLIV, p. 347. (1854.)

DWELLING HOUSES: THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS.

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II.

A very important matter in the sanitary administration of large towns, and an important matter for the consideration of every householder, is the regular and frequent removal of house refuse known as "dust." This consists chiefly of ashes and cinders; but, unfortunately, the dust bin or ash pit is only too convenient a receptacle for all kinds of refuse matters, including kitchen *debris*, and so, in a large number of instances, these receptacles, especially in hot weather, become excessively foul, and an abominable nuisance. If the dust were removed daily, as it should be wherever this is practicable, the mixture of organic matter with it would not be of great importance, but where this cannot be done, it is very necessary to insist that the dust bin shall be used for nothing but ashes, and that all organic kitchen refuse, such as cabbage leaves and stalks, shall be burnt. This can be done without any nuisance by piling them on the remains of the kitchen fire the last thing at night; thus they are gradually dried during the night, and help to light the fire in the morning. When dust is valuable to those who contract to remove it (for this work is generally let out to contractors by the parish authorities, although in several instances it is now being done with great advantage and saving to the ratepayers by the parish workmen themselves), there is no difficulty in getting it removed. The contractors are only too glad to get it, and even prosecute people who keep any of it back for their own uses. The cinders and ashes from dust bins are largely used in brickmaking, and so when the building trade is slack dust becomes worthless. The contractors, instead of paying for it, require to be paid considerable sums to take it away, and the less they take away, and the less frequently they call for it, the more advantage do they get out of their bargains. This has been the case for some years, and in one parish alone, that of Islington, where I was formerly Medical Officer of Health, the difference that it made to the sanitary authority in one year as compared with another only six years before, was no less than £6,257; whereas in the former year the sanitary authority received £2,200 from the contractors, in the latter they had to pay £4,057. No doubt, the best plan to get rid of such refuse matters would be to put them outside the door early in the morning in a box or bucket, to be called for every morning by the contractor's men, and this is already done in some places. Otherwise it is necessary for every householder to take care that the dust bin does not become a nuisance to himself or his neighbors, from too large an accumulation being allowed to remain in it, or from improper matters being thrown into it. Dust receptacles ought not to be kept inside of houses, as they very frequently are. Neither ought they to be built against the wall of the house, unless cased with an impervious layer of cement, to prevent emanations from them percolating through the walls into the interior of the house. They ought always to be covered with a sloping roof, so that the rain may run off; if rain water is allowed to get into them, they are much more likely to become a nuisance. Rain water pipes ought not to be carried through dust bins, for foul air from the latter will get into the pipe through a leaky joint, or a damaged place, and ascend it, causing a nuisance in one of the upper rooms, or elsewhere. I have known a serious nuisance caused in this way.

REMOVAL OF EXCRETAL MATTERS BY CONSERVANCY SYSTEMS.

Under the systems the excretal matters are either collected without any admixture, in receptacles known as cesspools, or they are mixed with ashes, and the other house refuse, forming what is called a "midden heap," and of these two old plans all the dry closets, pail and

tup systems, etc., may be said to be modifications. Cesspools were formerly largely used. especially for houses built on porous soils. A pit was dug into which the excretal matters were discharged and allowed to percolate away into the soil—frequently into neighboring wells. Often there was not only no pretence at making this pit impervious, but every facility was given to allow of the percolation of the foul water, etc., into the soil around. Thus the walls (when there were any) were made merely of rough blocks of stone placed one upon another. In some instances, these pits were not opened for many years together. Such cesspools were constructed long before water closets came into use, and were often retained after the introduction of these. In many instances they are placed underneath houses, and under the basements of large houses there are sometimes several of them. They form a serious nuisance, lasting for many years, as foul air from them finds its way into the house, even when there are no waste pipes directly connected with them, as there generally are, and thus they are very dangerous to health, even supposing that they are so placed as not to contaminate the water supply. In some towns it was, positively, formerly a practice to dig them down until a spring, or water of some kind was reached, in order that they might not require to be emptied. In all old houses it is impera tive to search diligently even for unused cesspools, and to trace the course of every pipe from every part of the house. In many instances, openings from the basement floor lead into disused cesspools, even in houses that have been drained, and the cesspools presumably abolished. A basement drain is not unfrequently allowed to discharge into an old cesspool, after a properly constructed sewer has been made to receive the refuse matters from the water closets. This is a source of great danger to the inmates of the house.

In some instances, however, cesspools are made of brickwork set in cement and lined internally with a layer of cement, so as to be impervious to water. They then require to be emptied periodically, a process which often causes a considerable nuisance, and they require, moreover, to be at a considerable distance from the house, and to be disconnected from the house drains and sewers in a manner that will be described in the next lecture. Not unfrequently, however, they are placed directly underneath the house or under the court yard, as is commonly the practice in Paris and many other continental cities and towns. Pipes are laid straight into them from the various stories of the house, and sometimes these are the only ventilating pipes through which foul air can escape. Occasionally they are made to overflow into sewers or drains, and sometimes a kind of strainer is placed inside them, so that the solid refuse may be collected, and the liquids allowed to escape into a sewer or drain. They used formerly to be emptied by hand and bucket, thereby causing an abominable nuisance, and the workmen employed for this purpose were frequent ly suffocated by the foul air, and suffered from inflammation of the eyes caused by the ammoniacal vapors Of late years, they have been emptied by hose into air-tight carts, from which the air has been previously exhausted by a powerful pump. This process, of course, causes less nuisance, and is not dangerous to the men employed, but, even with these improvements, the system is a very disagreeable one.

In some towns large midden heaps are still in vogue. The mixture of ashes and other house refuse with the excretal matters produces a drier mass, which, if not exposed to the rain, is considered to cause less nuisance than cesspools; but if dust bins are bad and are nuisances, as they most certainly are in a very large number of instances, midden heaps must be very much worse. Refuse matters become nuisances and injurious to health when they are allowed to remain in the vicinity of habitations. In all towns where refuse matters are not removed immediately there is a high death rate, and especially a high children's death rate, and in all towns (as Dr. Buchanan has shown in the ninth report of the Medical Officer of the Privy Council) where refuse matters are removed more speedily than they were formerly, the general death rate has been lessened. The improvements that have been made, then, in these conservancy systems, consist in diminishing in various ways the size of the receptacles, so that the refuse

matters cannot be collected in so large an amount, or kept for so long in and near the house, and in making receptacles impervious to water, so that liquids cannot escape from them into the soil around, nor water get into them. Sometimes the receptacles are drained into the sewers, so that the liquid part can run away, leaving the contents of the receptacle drier. In other cases they are not. The improvements in cesspools, then, have consisted in making them smaller and smaller, and, lastly, moveable—the *fosses mobiles* of the Continent; the pans, pails, tubs, etc., of some of our large towns. These movable receptacles are placed underneath the seats of the closets, fetched away when full by the scavenger, and replaced by the empty ones. They are, or ought to be, fitted with air-tight lids, so that as little nuisance as possible may be caused by carrying them to the carts; but, as may be expected, in many instances they are allowed to get too full, and a great nuisance is often caused in the houses. Nevertheless, this plan is a considerable improvement upon the plan of large buried cesspools. One of these pails that is largely in use is Haresceugh's spring-lid receptacle, a specimen of which may be seen in the Parkes Museum.

Similar improvements have been made in middens. The pits, in which the excretal matter and ashes are collected, have been made smaller and smaller, and impervious to water, until, at last, in some towns, they are above the ground, and consist only of the space beneath the seat of the closet made into an impervious receptacle, and usually drained into a sewer or drain. This, of course, necessitates their being emptied frequently, which is done by hand and spade labor. A capital plan is that adopted by Dr. Bayliss, the Medical Officer of Health for the West Kent Combined Districts, in which there is a ventilating shaft from the back part of the receptacle, rising above the roof of the closet. This allows the foul air to escape above the roof, while fresh air enters through openings cut in the door. Sometimes boxes or pails are used and removed periodically, as in the case of the tubs and pails, previously described as moveable cesspools, the only difference being that ashes, &c., are thrown in with a scoop, or by means of some self-acting apparatus. A contrivance which is now largely used, in towns where this system is in vogue, is Morell's cinder-sifting ash-closet, of which I have a model here. (A full-sized specimen may be seen in the Parkes Museum). The ashes are thrown on to the sifter, through the interstices of which the fine ash passes into a hopper, and the cinders fall off and may be collected and used again. The hopper is connected with the seat in such a manner that the weight of the person moves the seat a little, and jerks some of the fine ash down into the lower part of the hopper, from which it is thrown into the midden by another jerk when the person rises. Another contrivance of this kind is Moser's, which is also of very simple construction, and others are Taylor's and Wier's. The Eureka and Goux, and some other systems are varieties of the pail system in which an absorbent of some kind or another is used.

We now come to a consideration of the dry-earth system, which was brought into prominence by the Rev. Henry Moule. It consists in throwing over the excretal matters a certain quantity of dried and sifted earth, when an absorption takes place, and a compost is produced which is perfectly inoffensive to the sense of smell. The earth may be dried and used over and over again for five or six times, or even more, and any earth except chalk or sand will answer the purpose. It may be thrown by hand, or by a self-acting apparatus moved by the weight of the person, or by the door of the closet, or by a pull-up apparatus similar to that ordinarily used in water-closets. It will be seen at once that with this system there is not only something to be taken away, but something to be brought into the towns and into the houses—the dried earth; and this constitutes a very serious objection. However, it is an objection that might perhaps be waived, if the system could be satisfactorily worked on a large scale and by careless persons, for it is essential, in a large town at any rate, that a system for the removal of refuse matters must be used which can be worked by the most careless persons. When we consider that, if the supply of earth were

to fail for a day, a serious nuisance would be caused in every house; that if a servant throws a pail of slops into an earth-closet it becomes a cesspool; that the apparatus may get out of order, so that earth is not thrown in even though the hopper be full; and that an enormous quantity of earth would be required in every large town, we shall see that, at any rate for large towns, it is impracticable; and when added to this, we find the fact that one great argument in favor of the system, the supposed value of the manure produced, is entirely fallacious, it having been shown by the Sewage Committee of the Britsh Association, that the compost, even after passing six times through the closets, can only be regarded as a rich garden soil, and would not pay the cost of carriage even to a small distance; that, in fact, in the disintegration and decomposition of the organic matters that takes place in the mass, almost all the nitrogen is got rid of in some way or another, we see that one great argument for its use in towns disappears. We must remember, too, that deodorization is not necessarily disinfection, and, as Dr. Parkes pointed out, we do not know that the poisons—say of typhoid fever and cholera—are destroyed by being mixed with dried earth. It is even possible that they are preserved by it, and there can be no doubt that if the earth is not sufficiently dried, or if water is thrown on the mass, considerable danger would arise if the poisons of such diseases were present. While, however, the system is impracticable for large communities, it is one that has been found very useful indeed under suitable circumstances. It is useful for temporary large gatherings of people at flower shows, cattle shows, race meetings, volunteer reviews, &c., especially where there is a strict supervision, and where persons can be told off to attend to the distribution of the earth. Earth-closets are suitable for use in villages and country houses in the open air, but they ought not, in my opinion, to be placed indoors even in the country. Where the earth can be collected and dried on the spot, and the compost afterwards used upon the garden, the plan has been found very useful if only sufficient care be exercised, and no nuisance need be produced.

To sum up with regard to the conservancy plans, their very name condemns them one and all, for use in large towns at any rate, or in the interior of houses. One of the most important of sanitary principles is, that the refuse matters should be removed as speedily and as continuously as possible from the neighborhood of habitations, and the principle of all conservancy systems is that the refuse matters are to be kept in and about the house, at any rate, as long as they are not a nuisance, which of course means that, in a large number of cases, they become a serious nuisance. It is also obvious that the carriage of the refuse matters entails considerable cost under any of these systems, and so the less frequently they are removed the less does it cost, and what is detrimental to the life of the population becomes advantageous to the ratepayers. If the manure so collected were valuable, it might, of course, be made to pay the cost of collecting, but this is not the case as a rule, the only instance in which any of these systems have been made to pay being where the excretal matters have been collected in pails or tubs, unmixed with anything which would lessen their value. With all these systems, too, it is necessary to have some method for disposing of the slops and foul water generally, which cannot be allowed to run into the water-courses, as it would contaminate them, and so it is necessary to have sewers, the construction of which will be described in the next lecture.

As opposed to the conservancy systems, we have the water-carriage system, by means of which the refuse excretal matters are conveyed away in the foul water by gravitation through the sewers, and are thus removed from the houses as speedily and cheaply as possible by means of the pipes, which must in any case be provided in towns, to get rid of the foul water. The sewage is increased in bulk, but it is not rendered perceptibly fouler by this admixture. Indeed, as a rule, the sewage of a town supplied with water-closets is less foul than that of a town supplied with middens. Although, however, sewers are necessary in towns to carry the foul water away, in country places the slop water may be allowed to run into the surface drains,

provided they do not pass near wells, and this is best managed by means of a contrivance which I shall exhibit in another lecture.

The water-carriage system has disadvantages of its own, and requires special precautions to be taken, which, so far as they are connected with dwelling houses, will be described in the next two lectures.

SEWERAGE—MAIN SEWERS AND HOUSE BRANCHES, TRAPS, VENTILATION, &C.

Even where conservancy systems are used for the removal of refuse excretal matters, it is necessary to have some contrivance by means of which the foul waters can be got rid of. In country places, it may be discharged into ordinary agricultural drains laid beneath the garden. It then percolates into the soil, and serves to fertilize the crops. If, however, such waste water is thrown gradually down the traps and into the drains a small quantity at a time, the water escapes through the junctions of the first few pipes, and the fat and other solid matters become deposited in them, and soon choke up the pipes; so that it is necessary to collect the slop-water, and discharge it at intervals. The best contrivance for this purpose is Mr. Rogers Field's flush tank, of which I have here both an actual specimen and a large working model, kindly lent by Mr. Field. The slop-water is discharged over a loose iron grating at the top, and passes through a funnel-shaped aperture with a siphon bend at the bottom of it, which can also be lifted out, into the tank below. The discharge-pipe from this tank does not start from the top of it, but very near the bottom, is carried upwards to the top, and turns over and passes downwards to its outlet, which is at a lower level than the point from which the pipe began. This pipe is made in the earthenware end of the tank itself. Thus it will be seen that a siphon is produced, so that when the tank is filled to the top, and the shorter limb of the siphon also filled up to the bend, a sufficient quantity of water thrown in suddenly will start the siphon, and so empty the tank of its contents to the level from which the lower limb starts inside the tank. The discharge end of the siphon has a weir placed across it with a notch in it. By means of these contrivances, not only will a smaller quantity of water start the siphon, but a false action, which was found occasionally to take place, and which caused the water to dribble away without the tank being emptied, is prevented. Thus the whole body of water contained in the tank is made to rush through the drains, and the difficulty spoken of above is avoided. The tank also acts as a very good fat trap. In towns, however, it is necessary to have sewers for the removal of the foul water. Sewers ought to be impervious to water, so that their contents may not percolate into the soil around, and so drains which are made to dry the soil are obviously not fitted to be used as sewers. The larger sewers are usually made of bricks, and built with an oval section, this being preferable to the circular, and of course far better than any rectangular section. The bricks should be of the very hardest kind, and set in cement, and it is advisable to build the "invert," or lower part of the sewer, upon invert blocks made of stoneware. For smaller sized sewers stoneware pipes are the best. They should always be used for sewers not greater than eighteen inches in diameter. Larger sewers than these are cheaper made with bricks set in cement. Stoneware pipe sewers would be much more used than they are in towns, but for the fact that the estimated size of the sewers generally is usually larger than is required, and much larger than would be required if the rain and surface water were carried away by separate drains. The pipe of the sewer only requires to be large enough to carry away the water that can be discharged into it, and anything beyond that size is an absolute disadvantage, as it makes it more difficult to flush the sewers properly, for a larger pipe is insufficiently flushed by a quantity of water that would easily flush a smaller one. For flushing purposes it is best to have an arrangement by which a considerable quantity of water is delivered into the sewer at once, so that it may fill it, or nearly so. The same quantity of water delivered more gradually does not produce by any means the same effect. In laying sewers, whether main or house sewers, provision should always be made for making new connec-

tions, without cutting into the pipes. This may be done by putting in junctions at various points—a plan especially suited for private estates, where the points at which junction may be wanted will suggest themselves. With street mains more ample provision should be made. Mr. Jenning's pipes, which allow of the sewers being opened at any point without cutting the pipes, may be used. The pipes, in fact, have no sockets, the place of the sockets being supplied by divided rings, in one half of which the pipes are laid at their junctions, while the other half covers the upper part of the junction. With ordinary socket pipes, Messrs. Doulton's lidded pipes may be used with advantage. In these a third of the pipe can be taken off along the whole length of the pipe, and so junctions can be made, the pipes inspected, and cleaning rods pushed down them when necessary. The "capped" pipes made by Messrs. Jones & Company, of Bournemouth, are also useful. They are constructed in the following way:—A semi-circular or semi-elliptical hole is cut out of each pipe at its end, so that when the pipes are socketed a circular or elliptical hole is left at the junction between the two. These holes are closed by means of lids made for the purpose, which may be removed at any time, for the purposes of inspection, inserting a junction, &c. The above remarks apply to house branches as well as to main sewers, and it is very important not to omit the insertion of inspection pipes, of some kind or another, at proper intervals and suitable places, in house sewers, especially those of large mansions.

The main sewers should be freely ventilated at the level of the streets. All attempts to ventilate them in any other manner have been, without any exception, signal failures. If the ventilators, whether of main or of branch sewers, cause a nuisance, it is because there are not enough of them, or because the sewer is either badly laid or not properly flushed. In country places especially, cesspools are often the destination of the house sewers. Cesspools should never be made where it can be helped. It is far better to use the sewage on the land than to collect it in cesspools. However, in some places, cesspools are necessary, in which case they should always be made impervious to water, by being built of bricks set in cement and rendered in cement. The cesspool should not be under the house, but at some distance, and it must be ventilated. If near to the house, the ventilator should be carried up outside the wall of the house, and above the ridge of the roof. If at some distance, it may be ventilated either by means of an open galvanized iron grating, or by means of iron pipes carried up a tree and covered with wire network at the top. The cesspool should not overflow into a stream, or drain running into a stream, but on to the surface of the ground; and it is folly to build a second cesspool, as some people do, for the first one to overflow into, for, by the same argument, one might build any number —one after the other. Brick sewers should never be used under houses. The foul water soaks through them into the soil, and sediment is liable to accumulate in them. Rats eat their way through them, displacing the bricks and wandering about the house, and so not only does foul water get out of them into the soil, but foul air finds its way wherever the rats go, besides the fact that rats carry filth from the sewer itself about the house, and into the larder if they can get there. In this way, I have no doubt whatever, that milk and other foods have disease poisons frequently conveyed to them. Sewers made of glazed stoneware pipes should always be used for houses, except in cases where it may be better to use iron pipes, and they should always be laid outside the walls of the houses whenever it is practicable. They may require to be laid in a bed of concrete, as for example, where there is much made ground, or to be laid on hollow invert blocks in very wet soils. They should be jointed with cement, or, where a settlement is feared, with clay, finishing with a ring of cement. Clay alone is not advisable, as it is apt to get washed out of the joint, in which case the water runs out into the soil, and the solid matters accumulate in the sewer. If pipes, with Stanford's patent joint, made by Messrs. Doulton & Co. (of which I have some examples here) are used, no cement is required. The ends merely have to be greased and fitted

into one another. These pipes must be laid straight, or they will not fit together, and at bends it is often requisite to use ordinary socketed pipes. The fall of a house sewer should at least be 1 in 48, but a more considerable fall is preferable; 9-inch pipes may be used for very large mansions, especially if outbuildings are connected with the sewer, but, as a rule, for private houses 6-inch pipes with 4-inch branches are amply large. The junction of the branches should never be made at right angles, but always at an acute angle, and of course in the direction in which the water is going. At the end of the house sewer, in the main sewer, or cesspool, a swinging flap made with galvanized iron is frequently placed, with the view of keeping rats out of the house sewers. It may be of some use for this purpose, but is of little use for preventing the entrance of foul air, and as may be expected, these flaps are often out of order. It is also usual to place a water-trap of some kind upon the house sewer before it enters the main or cesspool. The kind formerly most used was what is known as the dipstone trap. The drain was deepened at the spot, and a piece of stone or slate inserted right across the drain from side to side, and reaching from the top down into the deepened part, two or three inches below the level of the bottom of the sewer. Water of course always remained in the deepened part, and so the dipstone running right across the drain dipped about two or three inches into this water. As it reached also to the top, and was built in, it obviously prevented the passage of the sewer air from the main sewer or cesspool into the house sewer, except, at any rate, that which could pass through the water in the trap. These traps were usually made rectangular, and were often very large, so that they were practically cesspools, and they still go by this name in some parts of the country. They may be much improved by making the end nearest to the house vertical, giving the opposite one a gentle slope, and fixing the dipstone, not vertically, but slanting in the direction in which water goes—rounding off the inside with concrete rendered in cement, so that there are no angles or corners. Thus the water falls vertically into the trap and flows out through a gentle incline. In such a trap very little accumulation occurs. Stoneware siphon traps are, however, now almost entirely used. They are frequently made with an upright piece from the lower part of the siphon, which may be continued by means of straight pipes up to near the surface of the ground, for the purposes of inspection, and of cleaning out the siphon should it get blocked up. This inspection opening is now sometimes made at the end of the siphon which is intended to be placed next to the house, so that if pipes are carried from it up to the surface of the ground, and an iron grating put on to it, a passage is formed which, under ordinary circumstances, acts (if precautions are taken which will be presently mentioned) as an entrance for air into the house sewer. The siphons also are now made with the limb into which the house sewer opens nearly vertical, while the opposite limb has a gentle slope upwards—the effect produced being that already mentioned. It is a considerable improvement, although not absolutely necessary, to increase the air inlet into the sewer at this point, that is to say, immediately on the side of the siphon trap, and instead of merely having a pipe taken up to the surface of the ground, to have a man-hole built in brickwork, and with channel pipes instead of whole pipes running along the bottom of it into the siphon. The channel pipes and one or two pipes beyond should be laid at a considerable fall, so that the water may rush down into the siphon and clear it out as much as possible. Branch pipes may be made to join the main in the man-hole by means of channel pipes, or even by whole pipes discharging into a gutter built above the channel pipe; or they may of course be taken into the house sewer at any point of its course. The man-hole may be covered by a galvanized iron-locked grating, if it is in such a position that gravel, &c., is not likely to get into it, but if in an area it is better to cover it with a locking iron door, and to have one or two 6-inch ventilating pipes from its upper part carried under the pavement area to the wall, up in the wall a short distance, and then opening out by gratings flush with the surface of the

wall. A junction pipe should be fixed immediately beyond the siphon and pipes brought from it through the wall of the man-hole, the end being filled with a plug, which can be removed for the purpose of cleaning the sewers beyond the siphon if necessary, or various earthenware disconnecting traps may be used. Potts's Edinburgh chambered sewer trap has the advantage of having a large air inlet, and a considerable fall in the trap itself. In many instances, with sewers already laid, sufficient fall cannot be got to introduce these traps. Weaver's trap is really a siphon, as already mentioned, with an upright air inlet leading into the limb of the siphon nearest to the house. Beyond the siphon an aperture is provided by means of which the main sewer, or cesspool beyond, can be ventilated, or which, if merely plugged, may serve as an inspection pipe, through which rods can be pushed, if necessary, down into the main sewers or cesspool. In Buchan's and Latham's traps the fall is quite vertical.

Stiff's interceptor may be described as a siphon-shaped trap, with a double dip, so that it has three compartments, with an open grating for the middle one. If any sewer air should pass under the first dip, it cannot get under the second, which is deeper, but will escape into the open air through the grating. Two inspection openings are provided, which may be also used as ventilating openings—the further one to ventilate the main sewer or cesspool, if necessary at this point, by means of a pipe running to the top of the house, and the one on the house side of the trap may be used as an air inlet. Professor Fleeming Jenkin has introduced the plan of using two siphon traps with an open grating between them. Dr. Woodhead has modified this by having a large earthenware receptacle, which all the house pipes enter underneath a large iron grating, with two siphons beyond the receptacle, one after another, and an upright pipe with an open grating between them. There is also a smaller upright pipe, with open grating at the top between the receptacle and the commencement of the first siphon. It is unfortunate that we cannot do without a water trap at all in disconnecting the house sewers from the mains, and I certainly do not think that any sufficient reason has been made out for having two traps one after another. At the highest point of the house sewer, or, if necessary, at the end of one or more branches, there should be a ventilating pipe, four inches in diameter, carried up above the eaves of the house or above the ridge of the roof, and not under or near any bedroom windows. This may be covered with a little conical cap, or merely with a piece of wire network, or with a cowl (preferably a fixed cowl) if it is required to be ornamental. Whether this pipe be covered with a cowl or not, air will, as a rule, enter at the air inlet at the lower end of the sewer, pass along it through its whole length, and escape by the ventilating pipe or pipes just mentioned, and no foul air can accumulate in any part of the sewer. If any foul air escapes at the air inlets, it acts as a warning to show that something is wrong; the siphon is stopped up, or there is an accumulation of foul matter in it, or in the sewer somewhere. When all is going right, no foul air will escape by these openings. The ventilating pipes may be made of iron if only used as ventilating pipes. When used also as soil-pipes they are better made of lead, as will be further shown in the next lecture. Rain-water pipes may be taken directly into the house sewer or its branches without any trap, provided that their joints are well filled and packed, and that they do not open at the top near to any bedroom windows, otherwise they must discharge over the surface of the yard or area. The surface gulleys for yards, &c., may be stoneware siphon gulleys, provided with galvanized iron gratings, which are better than stoneware gratings, as they are less liable to break. They are sometimes provided with openings in the side above the level of the water for the admission of waste pipes, &c. Dipstone traps are sometimes used, but are objectionable. McLandsborough's gulley is sometimes useful. It may be described as an iron dip-trap with three compartments, having several openings, into which pipes may be taken above the surface of the water. Jennings' receiver is also often useful, especially where the trap has to be low down, and upright pieces placed

one above another over it up to the level of the pavement. Pieces with openings are provided, so that drains coming from the inside of the house—the basement drains for instance—may be discharged into it, and so disconnected from the house sewer. Drains from the basement of a house ought not to open directly into the house sewer, but always into a disconnecting trap of some kind or another. Clark's gulleys are useful where much sludge is likely to be washed into the trap. They are provided with iron buckets that collect the sludge, and can be lifted out bodily. They are doubly and sometimes trebly trapped. The common bell trap, so often used, not only in areas, but in the basements of houses, is a most mischievous contrivance. It consists of an iron box with a pipe, which is connected with the sewer, standing up in it. The perforated cover of the box has an iron cup or bell-shaped piece fastened underneath it. Of course water stands in the box up to the level of the pipe which descends into the sewer. The bell on the perforated lid is so arranged that, when the lid or grating is in its place, the rim of the bell dips into the water around the vertical pipe. Even if the bell is in place, and whole, the trap is untrustworthy, because a very slight increase of pressure of air in the sewer will cause it to force its way through the small film of water into which the bell dips. It is objectionable because it soon becomes filled up with filth, and because, unless water is almost continually running through it, a sufficient amount evaporates to allow the sewer air to escape freely; but the great objection to it is that, when the cover is taken off, the bell is taken off too. The trap, such as it is, is gone, and the air from the sewer escapes freely into the house if the trap is inside the house. The covers are often taken off by servants, and left off, and are also frequently broken, and so the use of these traps should be discouraged as much as possible. The Mansergh trap is frequently useful in areas, as it serves also for the disconnection of the basement sinks, and provides a place of attachment for a ventilator for the house sewer. It consists of three compartments. Into an opening in the side of the first, the waste-pipe of a sink may be conducted. The water from this fills the first compartment up to the level of an aperture, through which it passes into the second, the pipe through which the water is conveyed into the first compartment being made to dip below the surface of the water in that compartment. Over the first and second compartments there is a loose iron lid with a grating over the second or middle compartment. From the second compartment, the water passes under a partition into the third, the outlet from which into the house sewer is above the lower edge of this partition, which itself extends from the top of the trap nearly to the bottom, so that it completely separates the air in the third compartment from that in the second, and dips beneath the level of the water in the two compartments. The top and sides of this third compartment are made of stoneware, so that it does not communicate with the external air, the outlet to the sewer being at one side, and an aperture to which a ventilating pipe may be attached in one of the other sides. Even if the last aperture be plugged up, and no ventilating pipe attached, any sewer air which can pass through the water from the third compartment into the middle one would escape by the grating into the open air, and could not get into the house, as the pipe from the house into the first compartment of the trap dips below the water. The cases in which it is more advisable to use this trap than ordinary siphon gulleys, will be mentioned in the next lecture.

WATER-CLOSETS, SINKS AND BATHS.—ARRANGEMENT OF PIPES, TRAPS, &C.

Water-closets.—The simplest form of water-closet is the common hopper closet, consisting of a conical basin with a stoneware siphon trap below it. There is nothing to get out of order in these closets, but they are liable to get stopped up through an insufficient amount of water being used in them, and the basins often get very foul from the same cause, and from the fact that no water remains in the basin. They are very often supplied with water by means of a ¾-inch service pipe, which cannot supply water enough to flush them properly. This pipe is frequently taken directly from a cistern supplying drinking water, or,

even where the water service is constant, directly from the main water pipes provided with an ordinary stop-cock, or, perhaps, with a screw-down tap—a very mischievous plan, as the taps are frequently left turned on, and the water allowed to run to waste, sometimes emptying the cistern, and allowing foul air to get into it. When such pipes are taken direct from the main, the results are even more serious, as, if the water is, for any reason, turned off in the latter, foul air, and even liquid and solid filth, may be soaked up into the water mains, and contaminate the water supplied next. To this cause a very serious outbreak of typhoid fever in Croydon has been traced by Dr. Buchanan. The supply pipes for these closets should not be less than 1¼-inch in diameter, and should not be connected directly with the drinking water cistern or with the main water-pipe, but with a water-waste preventing cistern holding two or three gallons—the quantity required to flush the closet. I have here several specimens of such cisterns, lent by Messrs. Hayward, Tyler & Co., and by Messrs. Tylor & Sons. They are supplied from the nearest water cistern, or, in the case of a constant supply, from the main water-pipe—the supply pipe being guarded by a ball valve. The pipe from this waste-preventer to the closet is guarded by a valve, frequently the conical one known as the spindle valve, which can be raised by means of a lever worked by a chain and ring. When the chain is pulled, the spindle valve is raised, and the two or three gallons contained in the water-waste preventer are discharged into the hopper closet, while at the same the the ball valve is also raised by the lever, so that no water can come into the waste-preventer while the chain is being pulled. It will be seen that this and similar contrivances not only prevent direct connection between the water-closet and the drinking water of the cistern or main water pipe, but also prevent an inordinate waste of water. Other water-waste preventers will be mentioned shortly. An improvement on the ordinary hopper closet is the "Artisan" closet, made by Messrs. Beard, Dent, & Hellyer, in which the hopper is provided with a flushing rim, which is far better than the old plan of shooting the water in at one side of the hopper. In the "Vortex" closet, made by the same firm, the siphon is much deeper than in the "Artizan" closet, and the water stands in the basin. A two-inch supply pipe is necessary, the water being discharged by a flushing rim, and also projected into the middle of the basin, as it is clear that a greater force of water is required to flush out so deep a siphon On the other side of the siphon is placed a ventilating pipe to carry away any foul air.

We now come to various forms of "Wash-out" closets, the first being Jennings' "Monkey" closet. In this, a small amount of water remains in the basin, the opening out of which into the siphon is not at the bottom, as in the case of the hopper closet, but on one side. The advantage of this form of closet is, that it is not possible, as is the case with hopper closets, for careless persons to go on using the closet without flushing it with water, as the soil remains in the basin until it is flushed out. Hopper closets, on the other hand, may be used for a long while without any supply of water at all, and this is the way in which pipes frequently get stopped up. In the monkey closet the basin and siphon are all in one piece of earthenware. In Woodward's "Wash out" closet the basin is provided with a flushing rim, and the siphon is separate from the basin, so that it can be turned in any direction necessary. In Bostel's "Excelsior" closet the basin and the siphon are in one piece of earthenware, and the outlet at the back of the basin. The water-supply pipe is made to enter the basin by two branches, one on each side, and a flushing rim is provided. At the back of the basin is a vertical opening leading directly into the siphon, by means of which anything improperly thrown into the closet can be removed. An over-flow-pipe is also provided, but this is, in most instances, useless. Dodd's "Wash-out" closet is somewhat similar in shape to the others, but has a ventilating pipe attached to the discharge pipe immediately beyond the siphon. An inch and a quarter supply pipe should be used with these closets, and where there is less than six feet fall, one and a half inch pipes may be used with advantage. Fowler's closets are

suitable for use in poor neighborhoods, especially when there is an insufficient supply of water. In this system, rain, sink and other waste waters are made to wash out the trap of the closet.

The closet apparatus most commonly used in the interior of houses is that known as the "pan" closet, and is a most mischievous contrivance. The basin is conical, and below it is placed a metal pan capable of holding water, into which the lower part of the basin dips. This pan can be moved by the pull-up apparatus of the closet inside a large iron box called the "container," placed under the seat of the closet, and into the top of which the conical basin is fixed. This "container" has a 4-inch outlet at the lower part of it, leading into a trap placed below the floor, the trap being generally a lead "D" trap, from which a 4-inch pipe passes to the soil-pipe, which conveys the refuse from the closets into the sewer. The great fault of the "pan" closet consists in the large iron "container," which is merely a reservoir for foul air, as it always becomes very filthy inside. When the pull-up apparatus is worked, the pan is swung from its position below the basin, and its contents thrown into the "container," the sides of which are splashed with foul matters, and cannot possibly be cleaned. Besides this, the container leads into the D-trap, which always contains foul matters, and gives off foul air into the container. At the same time that the contents of the pan are thrown into the container, foul air from the latter is forced into the house. This can only be partly remedied by providing a ventilating pipe for the container, and carrying it out of doors, but I have more than once seen a ventilating hole drilled into the container, and no pipe attached to it, so that foul air from the container was driven out with a puff that would blow out a candle, each time that the closet was used, and this in closets immediately connected with bedrooms. The D-trap should not be used at all either under closets or sinks. It consists of a lead box shaped like the letter D, placed thus, ᗡ. The outlet pipe starts close to the top at one end, and the inlet pipe passes down to an inch or so below the level of the lower part of the outlet. Of course water remains in this trap up to the level of the outlet, so that the inlet pipe dips into it an inch or more. The D-traps are never washed out thoroughly at each use of the closet. A deposit of foul matter takes place in them, and foul air is generated. This gradually corrodes the lead, and eats holes through it at the upper part of the trap. I have here several specimens of D-traps with holes eaten through them by the foul air. Such holes, of course, form a means of escape for the foul air from the sewer into the house. The trap is generally made of sheet lead, and not cast in one piece of lead; but an improved form has been made by Messrs. Gascoyne, which is cast in one piece, and in which the inlet pipe is placed at one end, so that there is no space left between it and the end of the trap, for paper, &c., to accumulate in. Instead of a D-trap, where a lead trap is used, it should be an S-trap or P-trap of 4-inch cast lead. This is flushed out by each use of the closet. A lead tray is usually placed on the floor underneath the closet apparatus, the trap being placed sometimes above and sometimes below it. The object of this tray is to prevent any overflow from the closet soaking into the floor and perhaps through into the ceiling below, causing serious annoyance, and perhaps a great nuisance. This tray is commonly called the "safe" of the closet, but, as generally constructed, any other word in the language would be more applicable to it. It is, of course, provided with a waste pipe, and this waste-pipe is almost invariably carried into the D-trap, when there is one below the safe, but it is not unfrequently carried straight into the soil-pipe, with or without a siphon bend on it. When carried into the D-trap, it is usually made to enter below the surface of the foul water therein contained, but I have not unfrequently seen them carried straight into the top of the trap, and so form a passage for foul air into the house. They ought not to be connected with any part of the water-closet apparatus, trap or soil-pipe, but ought to be carried straight through the wall to end in the open air, being merely provided with a small brass flapper to keep draughts out. The waste, or overflow pipes of cisterns, are frequently carried into the D-traps of closets, in which case foul matters get washed into the inside

of these pipes, and foul air from them contaminates the water in the cisterns. This is even a greater evil than the last, and the waste pipes of all cisterns, but more especially those used for the supply of drinking water, should, as stated in a previous lecture, be made to end in the open air.

We come now to valve closets, the numerous varieties of which are modifications of the original Bramah's valve closet. In this the aperture at the lowest part of the basin is closed by a water-tight valve, which can be moved in a small valve box, placed immediately below the basin, by means of the pull-up apparatus—the valve box itself being connected below with the trap. Thus, the necessity for the large iron container, so objectionable a part of the pan-closet, is done away with, and its place taken by a small box, in which the valve moves. As, however, the valve is water-tight, provision is made for the overflow of water from the basin, in case the latter should be filled to full, either by slops being thrown into it, or by the water continually running from the supply-pipe in consequence of a leaky valve. The overflow pipe starts from one side of the basin in which holes leading into it are peforated. It is then, as a rule, carried downwards into the valve box, having a small siphon bend on it before entering. The water from the supply-pipe, as it enters, is made to flow round the basin by an inner plate, generally made of metal, called the "spreader," or still better, in the improved form of valve-closet by means of a flushing rim. Thus, some of the water at each use of the closet passes through the holes leading into the overflow pipe; the object of this being to keep the siphon on that pipe charged with water, as it is clear that if this siphon is not charged, the overflow pipe ventilates the valve box, that is to say, the space below the valves, and the surface of the water in the trap below into the basin of the closet. Now, as a rule, the siphon trap on the overflow pipe does not remain charged with water, and even if it does, is of little use, for the following reasons—when by the pulling up of the handle the valve is made to move suddenly in the valve box, air from the latter is forced out through the water in the siphon bend of the overflow pipe, as any one can see, who will take the trouble to place a piece of moist tissue paper over the hole in the side of the basin leading into that pipe, and then work the handle of the closet. Thus foul air from the valve box is driven into the basin, even when the siphon on the overflow pipe is charged. Furthermore, as the mass of water in the basin rushes down through the valve box into the trap it carries the air along with it, and when the valve is closed runs out of the valve box, drawing air through the overflow pipe, and displacing the water in the siphon, which is in many cases left quite uncharged. Various remedies have been proposed for this. In Bolding's "Simplex" valve closet a small pipe is carried from the water-supply pipe into the overflow just above the siphon, with the view of supplying water direct to the siphon each time the closet is used. In Jennings' valve closets the overflow is trapped by means of a patent india-rubber ball trap, which is something like a Bower trap upside down. It is constructed so that the overflow water can displace the ball from the end of the water-pipe, and flow away round it, but any pressure of air from the valve box would only cause the ball to fit more closely against the end of the overflow pipe. In the valve closet made by Beard, Dent, and Hellyer, the overflow pipe is made much larger than usual, and the siphon deeper, so that it holds a larger quantity of water, and at the same time a ventilating pipe is inserted into the valve box, and should be carried through the wall to the outer air. By this means no accumulation of foul air in the valve box can take place, and any air that is drawn into it, while the water is passing through it, comes in through the ventilating pipe instead of through the overflow. It is quite right to ventilate the valve box, but the best way to deal with the overflow pipe is to disconnect it altogether from the valve box, and either carry it through the wall, placing a brass flap on the end of it, or to let it end over the waste pipe of the safe. Indeed, it is hardly necessary to have an overflow pipe at all, as if the basin does get full, all that will happen is that the water will flow over the top of it into the safe and run away. The advantage of this plan is that the exist-

ence of a leaky valve is found out immediately, and the disadvantage is that it is liable to wet the end part of the seat and apparatus below it. Lead D-traps are generally placed under these closets, but this should never be allowed. Siphon traps should always be used, for the reasons already mentioned. Some valve closets are made with a galvanized iron siphon trap that is to be placed wholly or partially above the floor, and is provided with a screw cap that can be taken off for the purpose of cleaning; such closets are made by Messrs. Tylor & Sons, and Messrs. Jennings. The latter also make closets, which may be called "plug" closets, the best known variety having the basin and siphon ball trap all in one piece of china. The plug closes the entrance from the basin into the siphon below, and is connected by a rod with the handle, which is vertically over it. By means of an india-rubber flange the plug is made to fit water-tight into the entrance of the siphon, and a body of water is kept in the basin above it, up to the level of the overflow, which is either made through the plug and the rod joining it with the handle, or by a separate trapped channel along side of it. A plug is also made to contain the patent ball trap mentioned above. It will be seen that in these closets, no valve box is necessary, and there is only a small air-space between the water in the trap and that in the basin. These closets are also made without any trap at all, in which case the overflow of the basin is carried, by a pipe, straight through the wall. Such trapless closets are often very useful on the ground floor, where the soil-pipe can be carried straight through the wall, and disconnected from the sewer by a ventilating trap outside.

We must now consider more in detail the arrangements for the supply of water to the basin. The simplest form of water-waste preventer has already been mentioned, but it must be remembered that the commonest plan for supplying closets with water, is to place a spindle valve in the bottom of a cistern somewhere above them, so as to guard the entrance into the pipe leading to the basin of the closet, and to work this valve by means of wires connected with the pull-up apparatus. The great disadvantage of this apparatus is that the wires get stretched by use, and have to be shortened from time to time. There is, obviously, also no provision against waste of water, for the water will run as long as the handle is held, or fastened up, until the cistern is empty. Neither is there any "regulator" to ensure a sufficient supply of water being delivered to the closet each time that the handle is pulled up, whether it is held up or not. I have here one kind of valve which achieves these two objects (lent by Messrs. Tylor & Sons), fixed in a cistern with glass sides, so that you may see its action. When the handle of the closet is worked the valve is raised, and if the handle is let go, the valve does not fall directly but gradually, so as to allow a certain quantity of flow out into the basin of the closet. But if the handle is held up (or down in the case of a ring and chain, as here) a metal weight which was carried up with the valve falls, and stops the flow of water. These valves may be used as cisterns, and connected with the pull-up apparatus by wires, or they may be placed in the small waste-preventing cistern already described, with the view of ensuring the use of a definite quantity of water each time. In another of these waste-preventing cisterns the pipe supplying the closet does not start from the bottom, but starts inside the cistern in the form of a siphon, which is so arranged that when the water is once started it all runs off. Another waste-preventer, of which I have a specimen here, has been recently invented by Mr. Jennings, Jr., and consists of a heavy metal cylinder with a piston inside it, the rod of which is the rod to which the handle of the closet is fixed. Upon this cylinder are two projections, one of which lifts the lever which turns on the water, and the other one which moves the valve. The piston is made so large that the cylinder adheres to it, and when the handle is pulled up the cylinder is, therefore, lifted with it, and the valve opened and the water turned on at the same time; but if the handle is held up too long the weight of the cylinder gradually overcomes its adhesion to the piston, and it falls, closing the valve of the closet and turning off the water at the same time. Thus, this water-waste preventer does not come into action at each use of the

closet, but only when it is wanted. Not only water-waste preventers, but regulator valves are used in all the best forms of closets. There are, as already hinted, valves that are so constructed that they allow a certain quantity of water to pass through them whether the handle of the closet be held up or not, so that the proper quantity of water is supplied even if the handle is pulled up and let go at once. The oldest and best known of these is Underhay's regulator valve. The valve itself is, of course, worked by a lever, and the rate at which the valve is closed depends upon the rate at which the lever falls. This rate is regulated by the fall of a piston in a cylinder, the escape of air from which can be controlled by means of a small tap, so that the rate at which the lever will fall and close the valve, and, therefore, the quantity of water which will pass into the basin each time that the handle is pulled up, can be regulated to a nicety. The commonest form of this regulator is known as the bellows regulator. Other regulator valves are Tylor's and Jennings', in which, by means of simple arrangements, the rate at which the lever falls and closes the valve can be controlled. When water is delivered on the constant service at high pressure, Common's waste preventer is sometimes used. In this the requisite quantity of water is collected under pressure in an iron cylinder, the air in which is compressed by the pressure of the water from the main. When the handle of the closet is pulled up, it moves a valve, which closes the pipe from the main, and opens that leading into the basin of the closet. The compressed air in the cylinder then expands, forcing the water before it into the closet, and no more water will come in from the main until the handle is put down again, when it can only flow into the cylinder, and not into the closet. Vessels containing disinfectants or deodorants are sometimes attached to closets in such a manner that a certain portion of disinfecting or deodorizing fluid is thrown into the water in the basin each time the closet is used; but, if closets are properly constructed, this is not necessary.

We next come to the soil pipe, which conveys the waste matters from the water closet to the sewer. Soil pipes are most frequently made of lead, and they should, as a general rule, be 4 inches in diameter. Formerly, when made of lead, they were necessarily seamed pipes, as drawn lead pipes were then unknown. Consequently, there were not only soldered joints at the ends of the lengths, but a soldered seam longitudinally the whole length of the pipe. These seamed pipes should never now be used, and where found should always be taken out, as the seam gives way sooner or later, even when the pipe is placed quite vertically, and it then allows foul air to escape into the house. Pipes of drawn lead should be used, so that the only joints are at the ends of the lengths, and these can be made, and are commonly made, more durable than the pipe itself, which is not the case with the seamed joints. Iron soil pipes are sometimes used, and, indeed, are preferred in climates where there are great variations of temperature, as they expand and contract less than lead ones do. But in this climate drawn lead soil pipes are preferable, especially if they are placed, as they frequently are, inside houses, in which position I should never allow an iron one to be fixed, on account of the difficulty of being sure that air-tight joints are made; and even outside a house leaden ones are to be prefered, although more expensive, because, when iron ones are used, it is usually necessary to put lead pieces in to receive the lead pipe from the closet, to prevent a joint between lead and iron being made inside the house, and however carefully this is done, it always looks like a patched up job. When lead pipes are placed outside houses, it is, however, necessary to have them cased to protect them from mischief or violence. The small additional expense is of little consequence, and it is better to have them cased throughout their entire length with galvanized iron. In order that they may not project too much, a chasing in the wall can be made sufficiently deep to receive about half the pipe. Stoneware pipes are also used for soil pipes, but are not to be recommended inside of houses, at any rate, on account of the numerous joints that have to be made. Occasionally, where work is "scamped," soil pipes are even made of zinc, and I have a specimen here of a D-trap made of very thin lead, with a zinc soil pipe attached. The latter has

been eaten through by the foul air, as might be expected. Foul air is also capable of perforating lead soil pipes, especially if they are not ventilated, and I have here a specimen of a lead soil pipe, which was taken from under the floor of a bedroom, where it had very little fall, and which is seen to be perfectly riddled with holes, eaten through the solid lead by the foul air which accumulated in the pipe. In order to ventilate a soil pipe, it is not sufficient merely to carry a small pipe, such as an inch or even a 2-inch pipe, from the upper part of it to the top of the house, but the 4-inch soil-pipe itself should be continued (full bore) to the top of the house, and should, as a rule, project above the ridge of the roof. It may be covered simply with a perforated conical cap, not fixed on to the top of the soil pipe, but fixed so as to stand a little above it, and not to obstruct the flow of air out of it, or two or three copper wires may be fixed across the top, so as to prevent leaves from getting into it. Cowls of any kind are quite unnecessary, at any rate in the great majority of instances. Where an air inlet is made into the house sewer, the soil pipe should be carried into the latter by means of a bend—no trap of any kind being placed at the foot of it; but where this is not the case, or where it is not proposed to ventilate the house sewer by means of the soil pipe, or where the soil pipe cannot be carried above the roof, it is advisable to place a disconnecting trap of some kind at the foot of the soil pipe outside the house. In any case it is necessary that provision should be made for a free passage of air through the soil pipe. Where the vertical soil pipe is at some distance from one or more closets, so that the branch pipes from the closets to the soil pipe are, perhaps, a few feet long, it is a good plan, and sometimes necessary, to carry small ventilating pipes from below the traps of the closet, and connect them to a pipe outside the house, which should be continued up above the roof. This will prevent an accumulation of foul air in the branch pipes, and will also prevent the water passing down the main soil pipe from drawing the water out of the traps of closets beneath. It has even been proposed by Mr. Norman Shaw to disconnect the branches of the soil pipes of the closets from the main soil pipe outside the house, by making them discharge into open heads, something like the heads of the rain water pipes; and Dr. Heron has devised a plan in which part of the branch pipe is movable, and so arranged that it is only connected with the main soil pipe when the lid of the closet is open, but is removed from it by the closing of the lid; while Mr. Buchan has proposed that the branch pipe should be a channel pipe, freely open to the air along the top.

Water closets should, whenever it is possible, be separated from the house by a ventilated lobby, or, at any rate, there should be two doors with special means of ventilation for the space between them, and this leads me to speak of Mr. Saxon Snell's invention, of which I have a full-sized model here, lent by Mr. Howard, the maker. In this, by means of an arrangement called "The Duplex Lid," the closet apparatus is placed, by the closing of the lid, in a shaft which is carried up above the roof of the house. The water supply apparatus is also connected with the lid, so that the lid has to be closed in order to flush the closet.

We come now to sinks and baths.

Of sinks there are various kinds. Sometimes sinks called "slop sinks" are provided to get rid of the dirty water, although where wash-out or hopper closets are used the slops may be thrown down them. The waste pipes from slop sinks should be provided with siphon traps, and are, as a rule, connected with the soil pipes. They are, in fact, looked upon in much the same light as water closets. The other upstairs sinks, as "housemaid's sinks," and the small sinks under taps, known as draw-off sinks, must not be connected with the soil pipe or water closet apparatus. Their waste pipes should always be provided with siphon traps immediately under the sinks, in order to prevent air coming into the house through these pipes, as it is rendered foul by so doing, but at the other end these waste pipes should always be disconnected from the house sewer by discharging into a pipe with an open head like a rain water pipe, or over a gully in the area. Scullery sinks should also be disconnected from the sewer, but there is a difference of opinion as to whether or not this should be by means

of a trap large enough to collect the fat from the greasy water thrown down there. If such a trap is used, it must contain a sufficient amount of cold water to cool at once the hot water from the sink that is thrown into it. But, in any case, the pipe from the sink should pass under an open grating before entering, such trap. The waste pipes from baths should also be invariably disconnected from the house sewer in the same way as those from sinks. The waste pipes of baths should be large, say two inches in diameter, not only so that they may be quickly emptied, but that the large body of water being discharged suddenly may be made to flush the house sewer. In large houses where there are laundries, this is a still more important matter. A bath should have a lead "safe" tray placed under it, the waste pipe of which must go straight through the wall of the house, and end in the open air. The disconnecting traps used in the areas for the waste pipes of sinks and baths may be either the ordinary siphon gully trap with a galvanized iron grating (the waste pipes being made to discharge either over the grating, or preferably, as a rule, through holes in the sides of the trap below the grating, but above the water in the siphon), or Mansergh's trap may be used, especially for scullery sinks or sinks on the basement floor.

To conclude. The principles that guide us in carrying out sanitary works are simple enough, but sufficient has been said in these lectures to convince every one that it is only by the minutest attention to details that we can hope to guard ourselves against the dangers that surround us, especially in the contrivances for the removal of refuse matters.

BRIDGING NAVIGABLE WATERS OF THE UNITED STATES.

Report of Gen. G. K. WARREN, in Annual Report of Chief of Engineers for 1879.

GRADES AND CURVATURES UPON BRIDGES AND APPROACHES.

Upon the distribution of the report upon bridging the Mississippi River between St. Paul, Minn., and St. Louis, Mo., some disappointment was felt that it contained no tabulated statement of the grades used upon the bridges. As a matter of fact, all that could be ascertained about the grades on the bridges was given in the description of each bridge or on the drawings of them. The bridges, excepting those of the wagon-way at St. Paul and the railway at St. Louis, were draw-bridges and the grades were level, or nearly so; a table of these grades was of little value.

Such a table, however, has been prepared for the Mississippi River and sent herewith, giving curvature also; and as it is only in high bridges that grade is important, we have taken the table of grades, &c., on the Ohio River bridges from the report of the Board of Engineers, printed in the Annual Report of the Chief of Engineers for 1871, page 425.

These two tables cover a considerable range of examples. The highest railway grade given is on the bridge at Louisville, Ky., where it reaches 1.49 feet per 100 feet.

The grade on the St. Louis Bridge is 1 foot in 100 feet, and this grade is also used at the St. Charles Bridge across the Missouri River. These grades require either special engines or low rates of speed, and there is difficulty in holding the rail to the ties to prevent its *crawling* under the action of the driving wheels of the locomotive and the vibrations of the bridge.

The question of grades has little importance whenever a draw-bridge is allowable to accommodate navigation. But whenever the bridge is for a railroad system requiring constant service for hours at a time, or where the large amount of navigation would require the

drawers of a draw-bridge to remain open for continuous passage of vessels for many hours at a time, the accommodation of both means of transportation requires high bridges.

On high bridges where the railroad business is large and considerable speed of transit is required, the grade should be kept as low as possible with due regard to economy of construction. Where, in such cases, high grades are used, the strength, and rigidity must be increased with the grade, or special locomotives or stationary power should be employed. The advantages which this latter method presents will permit of much higher grades than can be allowed by traction engines.

TABLE GIVING MAXIMUM OF GRADE AND CURVATURE ON BRIDGES AND APPROACHES ON THE MISSISSIPPI RIVER.*

[Data taken from Warren's Report on Bridging the Mississippi River. Annual Report Chief of Engineeers for 1878, Part II, pp. 900–1125.]

Name of Bridge.	Grade per 100 ft.		On Bridge or Approach.	Curvature.		On Bridge or Approach.
	Right Bank.	Left Bank.		Right Bank.	Left Bank.	
	Feet.	*Feet.*				
St. Paul Railway	0.5	0	Approach	4° curve	5° curve	Approach.
St. Paul Highway	5.0	0	Bridge	Tangent	Tangent	
Hastings Railway	0.3	0	Approach	2°	Tangent	Approach.
Winona Railway	1.0	08.	"	10°	Tangent	"
" "	....	05.	Bridge	.....	.....	
La Crosse Railway	0.4	05.	Approach	2°	6°	Approach.
Prairie du Chien Railway. (This is a ponton bridge with two sets of approaches—one for high stages, the other for low.)						
Dubuque Railway	0	0	.....	4°	9°	Approaches.
Clinton Railway	0	0	.....	0	0	
Rock Island Rail and Highway	....	....	.....	3½°	Tangent	Approach.
Keokuk Rail and Highway.	0	0.8	.....	6⅔°	"	"
Quincy Railway	0	0	.....	Tangent	4°	"
Hannibal Rail and Highway	0	0	.....	9½°	6°	"
Louisiana Railway	0	0	.....	8°	Tangent	"

* The Saint Paul Highway Bridge is the only high Bridge on the Mississippi from St. Louis to Fort Snelling. The channel-span is sixty-three feet above high water and eighty-five feet above low water. The others are swing draw-bridges, about ten feet above high water.

The following is a tabular statement of the principal features of the bridges over the Ohio, together with the cost of each bridge as far as ascertained. Nothing but the actual cost between abutments has been taken, all land damages and connections with main track having been excluded.

Name of Bridge.	Length of Approach from right bank.	Length of Approach from left bank.	Total Length, including approaches.	Maximum Grade per mile (equated.)	Maximum curvature.	Above Low Water.	Above Highest Water.	Maximum Local Rise.	Width at Low Water of channel openings on axis of bridge.	Cost.
	ft.	ft.	ft.		° ′	ft.	ft.	ft.	ft.	
Steubenville Railroad..	.....	.....	1,895.4	.....	.....	90	45	45	303¼	$1,000,000
Wheeling (Highway)...	.....	.....	980	253	.....	91½	48	43½	980	161,594
Bridgeport (Highway)..	.....	.....	638	.....	.....	53	9½	43½	212	68,500
Bellaire Railroad	1,490	864	4,001½	60.3	5	90	40	50	322 / 220	Unfinished
Parkersburg Railroad..	726	1,994	4,262	59.3	4.20	90	40	50	326½ / 326½	1,223,550
*Newport & Cincinnati Railroad, as commenced	950	230	2,961.5	57.2	10	71½	9	62½	400	*820,394
Newport and Cincinnati Railroad, as altered..	2,400	1,680	5,861.5	66.0	10	100	37½	62½	400	†1,109,089
Covington & Cincinnati (Highway)	.....	.....	1,619	283	.....	103	40½	62½	1,005	1,480,000
Louisville Railroad....	.....	.....	5,218⅝	79.1	.....	96½	45½	51	380 / 352½	1,615,120
Paducah Railroad.....	. ....	... ..	.....	.....	.....	....	....	52¼	.....	Not begun

NOTE.—The lengths of earthen embankments are not included in the above.

G. K. WARREN,

Lieut. Col. Engineers and Brevt. Maj. Gen.

* This bridge was designed and nearly completed with the following grades and alignment: commencing at a point 750 from the abutment on the Newport side, the grade was 0.2393 foot per 100 to the end of the first span, or 882 feet, then level over seven spans, 1457.4 feet; then a grade of 0.465 foot per 100 on the last two spans, and 100 feet of the approach on a curve of 609 feet radius; then 0.8 foot to the 100 for 450 feet on a curve of 573 feet radius; then 0.8 per 100 on a tangent until the main line is reached. The Board of Engineers reported that the bridge as being built would prove a serious obstruction to navigation and that it should be raised 28½ feet to give 100 feet headway at lowest water, and 37½ feet at highest water. An estimate was made for doing this by lengthening the approaches on the same alignment. In this modification the maximum grade adopted for the approaches was 66 feet per mile, on tangents, for the reason that this was the ruling grade of the railroad on the Kentucky side, which had grades of 60 feet to the mile on 6° curves.

The raising of the bridge as recommended by the Board was ordered by Congress. It is not known what the new grades are as reconstructed, but they are in excess of those in the engineering board's plan, the height being the same while the approaches were not lengthened or the alignment changed.

† Estimated.

THE NATURE OF ELECTRICITY.*

From "Nature."

ON surveying the wide sea upon which the numerous and varied practical applications of electricity are launched for the subject of this evening's address, I have been puzzled to steer a course that shall avoid the dazzling shoals of theory on the one hand, and the dry hard rocks of practice on the other, Hypothesis is a veritable Scylla that captivates the imagination and often sends the visionary to destruction, while practice alone is a hard-hearted Charybdis that lures the matter-of-fact practical man to folly and expense. Practice must be tempered with theory to utilize advantageously the great forces of nature, and theory itself must be based on practice, or on facts, to be comprehensive and acceptable. Hence success is the offspring of the marriage of practice and theory, and, therefore, as the two are so intimately connected, I have determined to steer a middle course to-night to survey the progress of each in our profession, and to show their mutual relationship.

* Abstract of the Inaugural Address to the Society of Telegraph Engineers, by Mr. William Henry Preece (President), delivered January 28, 1880. Revised by the author.

What is theory? It is an explanation of the hidden cause of certain effects that are evident to the senses. It is an effort of the imagination to account for operations that are in themselves invisible and insensible, but which result in facts that are observable and known. Thus, the movements of all those bright bodies by which

> "The floor of heaven
> Is thick inlaid with patines of bright gold,"

are explained by the theory of gravity. Their appearance, vagaries, and beauties are accounted for by the undulatory theory of light. The warmth that the monarch of them all shed upon this earth countless ages ago, and that is now restored to us in our household fires, is explicable on the molecular theory of heat. The constitution of matter and its various states of solid, liquid, and gas, are completely explained by the atomic theory of Democritus and Dalton, and the modern kinetic theory of gases.

It is impossible for a practical man who has devoted more than a quarter of a century to the application of electricity to useful purposes, to avoid devoting much contemplation to the nature of the agent which he has to make use of. Is there a member of this society who has not striven to peer into the region of the unknown, who has not speculated on the power he uses, or who has not formed some conception in his mind of the nature of electricity? Yet it is remarkable that the answer to the question, What is electricity? cannot even now be given with authority. Faraday, our great apostle, whose researches should be every electrician's bible, declined to venture an answer, nor did he ever directly formulate his ideas on the subject, though his publications indicate pretty clearly, and with no uncertain sound, what they were. Clerk-Maxwell, who, while he overthrew all existing theories, failed to supply their place before he was so untimely removed from us. Sir William Thomson, in his published papers, always carefully eschews the consideration of any physical theory of electricity. The French electricians simply use the one-fluid theory as a convenience of language, while the Germans, as a rule, employ the two-fluid theory merely for mathematical purposes. Hence there is no recognized theory of electricity. Some maintain with Du Fay or with Franklin, that it is a form of matter —a substance; others, following Faraday and Grove, consider it a form of force—a motion—like heat and light. It must be either one or the other. There is no other category in which to class it. If it is not a form of matter it must be a form of force. The question I propose to discuss is, therefore, Is electricity a form of matter, or is it a form of force?

In discussing such a vexed question it is necessary to be very precise in language to avoid any misconception of my meaning, therefore I will define both matter and force in the sense in which I use those terms. *Matter* is that which can be perceived by the senses, or can be acted upon by force. It is characterized by weight, inertia, and elasticity. *Force* is that which produces, or tends to produce, the motion of matter. It may be pressure, tension, attraction, repulsion, or anything capable of causing alteration in the natural state of rest or of existing motion of matter.

Matter is found in either the solid, liquid, gaseous or ultra-gaseous state, and it occupies space. It consists of molecules and atoms. The *atom* is the smallest indivisible part of an element, and a group of atoms of the same or of different elements forms the *molecule*, which has a definite magnitude and is unalterable in form for each substance. The *mass* of a substance is the aggregate of the molecules of which it is composed. There is no generation or destruction of atoms. The indestructibility of matter is a fixed law in nature. The size of the molecule is approximately known. Sir William Thomson says: "If we conceive a sphere of water as large as a pea to be magnified to the size of the earth, each molecule being magnified to the same extent, the magnified structure would be coarser-grained than a heap of small lead shot, but less coarse-grained than a heap of cricket balls." Fifty million molecules ranged in single file would occupy an inch. They are highly elastic, and unless interfered with would move with constant velocity in straight lines. When they can move about freely without interfering with each other's proceedings, we have the ultra-gaseous state of

Crookes, a state found only in very high vacua and under certain adventitious circumstances. When they collide and impinge on each other according to the law of the impact of elastic bodies, interfering with each other's path, we have *gases* as we know them; when their mean free path is so reduced as to bring them within the sphere of mutual attraction, without too narrowly restricting their play, we have *liquids;* when the attraction becomes cohesion and the motion of the molecule is confined to its own sphere, we have *solids.* The number of molecules in a given volume of gas is known, and their velocity calculated. In hydrogen the velocity at 0° Cent. is 6,097 feet per second, the number being 10^{23} per cubic inch. The mean free path of a molecule in air at ordinary pressure is the ten-thousandth part of a millimeter. Besides their constant motion in straight lines the molecules may be set in vibration, rotation, or any other kind of relative motion whatever.

This is the atomic theory of matter born in the brain of Democritis, "the laughing philosopher," 2,300 years ago; preached by Epicurus in Athens, and taught by Lucretius in Rome before the Christian era; lying dormant for eighteen centuries, until it was formulated by Dalton in the last century, and removed from the region of pure speculation by Joule, Clausius, Clerk-Maxwell, and Crookes during our days.

The definition of force shows us that whatever changes or tends to change the motion of matter (or of the molecules of which it is composed), by altering either its direction or its magnitude, is a form of force. Thus gravity is a form of force, for it attracts all matter to the center of the earth, and it is measured by the rate per second at which a body acquires a velocity in this direction when falling freely at a given spot. Heat is a form of force, for it throws the molecules of matter into violent vibration, or it increases the velocity of their motion in straight lines, which thus becomes the measure of its heat or its *temperature.* Light is a form of force, for it is produced by the undulation of the molecules of matter, and it is transmitted by the undulations of that medium called Ether, which fills all space.

When we take a given free mass and impress upon it a given force, we throw that mass into motion; for instance, when we fire a loaded cannon, we have imparted to the ball "*energy*," and in virtue of the motion of the ball, this energy is called "*kinetic.*" Again, if we lift the ball to a certain height above the earth's surface—say to the top of a tower—and let it remain there, we have again imparted to it "energy," but this time it is called "*potential*," for it is dormant or resting. In each case the energy possessed by the ball is the exact equivalent of the work done upon it, that is, of the force impressed and the distance through which it has acted. The motion of the ball is readily transferred to the motion of the individual molecules of the ball. When, in the first case adduced, the ball strikes the side of a ship or a target, its kinetic energy is thus converted into light and heat, which is molecular motion; or, in the second case, when it is allowed to fall, its potential energy is converted into kinetic energy, which again, on coming in contact with the ground, is converted into molecular motion or heat. Energy is always either potential or kinetic, and one of the most remarkable generalizations of modern days is the grand principle of the conservation of energy, which implies that the total energy of the universe is a quantity which can neither be increased nor diminished, though it may be transformed into any of the forms of which energy is susceptible. Energy is therefore as indestructible as matter. All the recent advances in the science of heat have been due to the discovery of this principle, and its application to electricity has gone far to remove that science from the hypothetical state in which it has existed so long.

My purpose is to contend that electricity is not a form of matter but a form of force, and that all its effects are evident to us in one or other of the several forms of energy characterized by the motions of molecules or of mass.

It is interesting to trace the historical growth of theories. The uncultivated human intellect cannot soar above its own limited sphere of childish observation. Whatever is mysterious and incomprehensible in nature is attributed to that which is equally mysterious and incomprehensible. Life has ever been of

this character, and heat, magnetism, electricity, and many other unaccountable physical phenomena, have each in their turn been supposed to be causes of life. Even now there are those who would attribute exceptional and peculiar phenomena to spiritual agencies.

Heat was thought by the Greeks to be an animal that bit. It was then for many centuries thought to be a fluid which, entering into bodies, like mercury, made them swell, and this idea existed until this generation, when Rumford showed it to be a kind of motion, and Joule made it a quantitative form of energy.

Thales of Miletus thought that the magnet was endowed with a sort of immaterial spirit, and to possess a species of animation. The Greeks knew also that rubbed amber attracted bits of straw, and supposed it to be endowed with life. Even Boyle, as late as 1675, imagined it to emit a sort of glutinous effluvium which laid hold of small bodies and pulled them towards the excited body. Du Fay in 1733 conceived the double fluid theory, and Franklin in 1747 invented the single fluid theory. Cavendish in 1771 supplied some of the deficiencies of Franklin's theory, but it was Faraday who first exploded the fluid notion and originated the molecular theory of electricity, while Grove boldly classed electricity with light and heat as correlated forces and mere modes of motion.

Light was thought by the Platonists to be the consequence of something emitted from the eye meeting with certain emanations from the surface of things, but no theory of light properly so called was attempted until Newton produced his celebrated corpuscular theory in 1670, which has lasted until the present day. Even as late as 1816 Faraday himself said: "The conclusion that is now generally received appears to be, that light consists of minute atoms of matter of an octahedral form, possessing polarity, and varying in size or in velocity."* Although Huygens in Newton's own time conceived the undulatory theory, the superior authority of the great English philosopher overshadowed the lesser light, and it was not until Young and Fresnel at the commencement of this century took the matter up, that the present theory of light took firm root. Thus we see that all these sciences have passed through the same stages of mystery and fancy, and it is only within the present generation that they have emerged from the mythical to the natural, from mere hypothesis to true theory. *Hypothesis* is an imaginary explanation of the cause of certain phenomena which remains to be shown probable or to be proved true. *Theory* is the supposition when it has been shown to be highly probable and all known facts are in agreement with its truth.

A theory, therefore, to be valid and true, must agree with every observed fact; it must not conflict with natural laws; it must suggest new experience, and it should lead to further developments. A theory is absurd if it supposes an agent to act in a manner unknown in all other cases. The fluid theories of electricity are merely descriptive, they do not agree with every observed fact; they have never prompted the invention of a single new experiment or led to any development. They suppose an agent unknown in other cases and opposed to natural laws. Incomplete theories die a natural death: thus Descartes' vortices, Newton's corpuscular theory of light, the fluid theory of heat, Stahl's phlogiston, Nature abhorring a vacuum, have all disappeared, while complete theories, such as that of gravity, the laws of motion, the conservation of energy, the undulatory theory of light, not only remain, but suggest new fields of inquiry, open out fresh pastures, carry truth and conviction with them, and have led to the most wonderful predictions. The fluid theories of electricity are certainly incomplete, and they deserve a speedy interment. We have to assume the existence of two substances of opposite qualities which mutually annihilate each other on combination—a self-evident absurdity, for the conception of matter involves indestructibility. Franklin imagined his one fluid to be an element of glass; remove electricity, and glass would lose its virtues and properties, and thus glass was to give out its electricity for ever and a day, without loss of weight or sensible diminution. It was to be devoid of dimensions, inertia, weight, and elasticity, and is therefore outside the pale of our definition.

* "Life," vol. I, p. 216.

Electricity is therefore not a form of matter. Hence, according to our reasoning, it must be a form of force.

But can we not prove that it is a form of force? Certainly.

Let us first argue from analogy. We know that sound, heat, and light are modes of motion; in what respect does electricity agree with these forms of force?

The fundamental law of electro-statics is that two bodies charged with opposite electricities attract each other with a force dependent on the square of the distance separating them. Whatever influence or power spreads from a point and expands uniformly through space varies in intensity as the square of the distance for the area over which it is spread increases as the square of the radius. This is the case with gravity, light, sound and heat, which are known forms of force. It is also the case with electricity and magnetism, which ought therefore to be similar forms of force.

If we regard the velocity of transmission of certain electrical disturbances through space we have every reason to believe that it is the same as that of radiant heat and light. In 1859 two observers in different parts of the country (Messrs. Carrington and Hodgson) saw simultaneously a bright spot break out on the face of the sun, whose duration was only five minutes. Exactly at this time the magnetic needles at Kew were jerked, and the telegraph wires all over the world were disturbed. Telegraphists were shocked, and an apparatus in Norway was set on fire. Auroras followed, and all the effects of powerful magnetic storms. Moreover, the periods of sun spots, earth currents and magnetic storms follow the same cycle of about eleven years. Dr. Hopkinson has shown that this electric disturbance through space is as mechanical as its action through short distances, and is therefore identical with the ordinary strains of elastic matter subject to distortion by mechanical force. But Clerk-Maxwell has gone beyond this, and has shown that the velocity of light is identical with that of the propagation of electrical disturbances through space as well as through air and other transparent media. Hence, as light is admitted to be a mode of motion identical with radiant heat, electricity must be of the same category.

There is such a remarkable analogy between the conductivity of the different metals for heat and for electricity—indeed, there is every reason to believe that if the metals were pure, the order and ratio of conductivity would be identical—that it is impossible to resist the conclusion that the mode of transmission in each case is the same. Mr. Chandler Roberts, who, using Prof. Hughes' beautiful induction balance, showed, by experiments on a comprehensive series of alloys, that the curves indicating the induction-balance effect closely resemble their curves of electrical resistance. He was also able to demonstrate that the induction-balance curve of the copper-tin alloys is almost identical with the curve of the conductivity of heat—a conclusion of much interest; and he pointed out that we might look with confidence to being able to ascertain, by the aid of the induction-balance, whether the relation between the conductivity of heat and electricity is really as simple as it has hitherto been supposed to be. Moreover, when a wire conveys a current of electricity it is warmed, as the strength of current is increased it is heated and eventually rendered incandescent. The ultimate form which every electric current takes is heat. The wire of every telegraph is warmed in proportion to the currents it transmits. Joule showed that when this heat is produced by a current generated in a battery by chemical force, its amount is exactly equivalent to that which would have been evolved by the direct combination of the atoms. The conducting power of all bodies is affected by heat, and some even, like selenium, by light. Hence, as we know that in the case of heat and light conduction is molecular vibration, we reasonably conclude that it is the same with electricity. In fact, it is impossible to account for these phenomena except on the assumption of the motion of the molecules.

The magnificent researches of Dr. Warren de la Rue and Dr. Hugo Müller on the electric discharge with the 11,000 cells of chloride of silvery battery that the former philosopher has provided himself with in his celebrated laboratory, have shown indisputably that the discharge in air or in gases under various

pressures is a function of the molecules filling the space through which the discharge occurs. In fact, the resistance of the discharge between parallel flat surfaces is as the number of molecules intervening between them; and they show that during electrical discharge in a gas there is a sudden and considerable pressure produced by a projection of the molecules against the sides of the containing vessel distinct from that caused by heat, and unquestionably due to the molecular action of electrification. The long-continued and patient researches which these eminent physicists are carrying out prove beyond doubt that electrical discharge is simply molecular disturbance. In reality, the fact that no discharge occurs through a perfect vacuum is a crucial proof of the molecular theory.

Some recent very remarkable researches of M. Planté with his rheo-static machine* have shown that fine wires conveying powerful currents are wrinkled up into well-defined regular nodes, that these effects are accompanied by a peculiar crackling, and that the wire itself becomes brittle, giving clear indication of the vibratory motion of the molecules. He gives as the result of his inquiry, that electrical transmission is the result of a series of very rapid vibration of the more or less elastic matter which it traverses, and he points out certain analogies between electric motion and sonorous vibrations. This view is supported by the researches of Professors Ayrton and Perry† on the viscosity of dielectrics.

Prof. Challis, of Cambridge, has extended this view so far as to embrace magnetism, electricity, light, heat, and gravity in one category of physical force, and to assert that they all result from motions and pressures of a uniform elastic fluid medium pervading all space not occupied by atoms. His views, however, have not received much attention, for they are not based on the foundation of any new facts, and they are utterly subversive of many cherished principles deeply rooted in the scientific mind. It is to be observed, however, that he regards electricity as a form of force.

Mr. Crookes, in his recent beautiful experimental researches into molecular physics in high vacua, has still more conclusively proved the connection that exists between electrical action and molecular motion. In fact, his experiments are so brilliant, his expositions so lucid, that one can fancy one sees with the eye of the body that peculiar play of the molecules which can be evident only to the eye of the mind. Not only has Mr. Crookes established as a physical fact the kinetic theory of gases and the molecular constitution of matter, but he has indicated the existence of a fourth state of matter where the molecules fly about without mutual let or hindrance. He has also led us to doubt the truth of the generally received opinion that an electric current flows from the positive to the negative electrode. It would appear from his investigations that the reverse is the case. Be that as it may, he has added one story to the structure of the molecular theory of electricity.

The criterion of a good theory is, however, its power of prediction. A false theory has never led to prevision. Neither the corpuscular theory of light, nor the fluid theories of heat and electricity, ever led to the prediction of something of which eyes had not seen nor ears heard. The triumphs of prediction in astronomy, sound, light, and heat are innumerable. Faraday predicted the effect of induction in lowering the velocity of currents of electricity and the action of magnetism on a ray of light. Sir William Thomson predicted that a current in passing from a hot to a cold part of a copper bar would heat the point of contact, while in an iron bar it cools it. Peltier predicted the cooling effect of currents on the junctions of thermo-electric pairs.

But the true identity of these physical effects is conclusively shown by their quantitative character and by their adhesion to the law of the conservation of energy. Take the case of the electric light: the consumption of coal in a furnace generates steam, the steam works an engine, the engine rotates a coil of wire in a magnetic field, the motion of the coil in this field induces currents of electricity in the wire, these currents of electricity produce an arc, and thereby heat and light. The energy of the coal is transformed into heat and

* *Comptes Rendus* LXXXIX, pp. 76—80, 1879.

† *Proc. Roy. Soc.* pp. 7—8, 1878.

light through the intermediate agency of electricity. Is it possible to conceive that this intermediate agency is anything but a form of energy? Take the case of the Bell telephone: the energy of the voice produces the energy of sonorous vibration in the air, the vibrations of the air cause the vibrations of the iron disk, the vibrations of the disk vary the magnetism of the magnetic field, this produces currents of electricity in a small coil in this field which vary the magnetism of the distant magnet, which in its turn throws its disk armature into vibration, and thereby repeats at the distant station the sonorous vibrations of the air, and thus reproduces the energy of the voice. A tuning fork comes to rest sooner in front of a telephone than when it is allowed to vibrate freely in air. Here we have the energy of the fork passing through the several stages indicated above, and ultimately coming out in its original form. The energy of sonorous vibrations at the distant station is that lost by the vibrating tuning fork.

Is it possible to assume that in this cycle of changes energy has been transformed into matter and matter again formed into energy? It is impossible and absurd. Clerk-Maxwell said:—"When the appearance of one thing is strictly connected with the disappearance of another, so that the amount which exists of the one thing depends on and can be calculated from the amount of the other which has disappeared, we conclude that the one has been formed at the expense of the other, and that they are both forms of the same thing."

Would it be possible to light the streets of New York by the energy of the falling water at Niagara, as has been suggested by our Past President, Dr. Siemens, if the cycle of changes from the one spot to the other were not all different forms of this same energy? Would it be possible to plow a field a mile away from the source of motive power of the transmitting medium if the electric currents were not forms of the same power? Electricity in its effects is and must be a form of energy.

The final stage into which any physical theory grows is that in which every action can be expressed in mathematical language, where every phenomenon is calculated upon an absolute physical basis, and where we can foretell exactly what will occur under any possible emergency. This is the present condition of the science of electricity. We can calculate exactly how much steam power is required to generate a given current to produce a given light. We can tell precisely what dimensions of cable are necessary to give a certain number of words per minute on the other side of the globe. If a fault develop itself in a long cable through the gastronomic propensities of a thoughtless young teredo, we can calculate to within a few fathoms the locality of his edacious depredation.

Clerk-Maxwell,* in his classical work on electricity, has used a somewhat curious argumen tto show that electricity is not, like heat, a form of energy. He says that energy is produced by the multiplication of "electricity" and "potential," and that it is impossible that electricity and energy should be quantities of the same category, for electricity is only one of the factors of energy, the other factor being "potential." But this does not militate in any way against the force of the argument, for in nature we can no more do so that we can separate heat and temperature. Energy usually appears as the product of two factors, and it is the equivalent of the work done. Thus *Potential energy* is the product of mass and gravitation acting through a distance. *Kinetic energy* is the product of mass and the half square of velocity. The energy of fluids is the product of volume and pressure. The energy of heat is made up of heat and temperature, and the energy of electricity is the product of electricity and potential. Hence it is that electricity, *per se*, may be said to be a form of force, while all its effects as known to us are forms of energy. Force alone cannot produce energy; it must be force and something else. Force is the power of producing energy, and it must have something on which to produce it. Hence matter is always present; and thus, though heat, light and electricity are forms of motion, they are in reality properties of matter from which they are inseparable. They are evident to us through the play of the molecules of

* Vol. I, p. 30.

matter, and thus are properly called molecular forces.

Earth currents have been a favorite subject of inquiry of mine for many years. I have always entertained the idea that they are directly due to the action of the sun. Some disturbance in the sun causes, by induction, a variation in the distribution of the lines of potential on the earth's surface, and produces the conditions required for these currents. I have many facts to support this hypothesis, but I want more to confirm it. Profs. Ayrton and Perry have developed a theory of terrestrial magnetism based on the assumption that the earth is a highly electrified sphere, which not only coincides well with facts, but which tends greatly to support my views. I want observers to record the times of daily maxima and minima. I want them especially to note during those periods of unusual disturbance the direction of the circuits which are *not* affected, for they would give the direction of the lines of equi-potential. This not only offers a useful field of observation, but its failure or success will illustrate the modern method of scientific research, when the brain suggests to the hand and the eye what they have to do, and what they have to look for.

THE PANAMA CANAL.

By Captain BEDFORD PIM, R. N., M. P.

From "Journal of the Society of Arts."

PART II.

CENTRAL AMERICA

In defining the boundaries of Central America, I shall not restrict myself to the narrowest part, commonly called the Isthmus of Panama, but include the entire country, from the first narrowing of the lands of North America at the Isthmus of Tehuantepec, between the 16th and 18th parallel of north latitude, and 94th meridian of west longitudes, to its expansion into South America at Darien in the 7th parallel of north latitude and 77th west meridian. In this definition I have been guided, not by political divisions, but by what appear to be the strict geographical limits of the center of the New World.

Central America, then, lies between the 7th and 18th parallels of north latitude, and the 74th and 94th of west longitude; its least breadth from sea to sea is 27 miles at lat. 9° N., long. 79° W. The extent of its coast line, counting all its sinuosities, is about 3,000 miles, its length from end to end about 1,350 miles, its direction north-west and south-east, and its area about 300,000 square miles, or about the size of Great Britain and France put together.

SUEZ AND PANAMA.

It is hardly possible to conceive anything more widely different than the nature of the connecting links joining together the continents of the Old and New Worlds. In the former we have a broad, flat, low expanse of parched and arid country, rather more than 70 miles across—a complete desert; in the latter, a mountainous surface, and very irregular coast line, extending over many hundreds of miles, teeming with animal and vegetable life, and only, at its narrowest part, about half the width of the Old World Isthmus. There is another striking dissimilarity—the one possesses the earliest records of the human race in readable hieroglyphics, and is crowded with historical associations of the deepest interest to mankind, whilst the other is a comparatively modern addition to the history of the world, with writings still an enigma to science.

STATES AND PROVINCES.

There are so many well-written accounts of Central America, from its conquest and partial occupation (the first European settlement was formed by Columbus in 1502), until the final expulsion of the Spaniards, between the years 1820 and 1823, that it seems superfluous to enter upon its earlier history; and I shall, therefore, simply confine myself to a brief notice of the various States and dependencies.

Within the limits I have defined as the natural boundaries of the center of the New World are included two provinces of New Granada (Panama and Veraguas, commonly called the Isthmus of Panama), two of Mexico (Yucatan and Chiapas), an English colony (Belize, or British Honduras), five republics (Costa Rica, San Salvador, Honduras, and the Bay Islands, Guatemala, and Nicaragua), and the Indian kingdom of Mosquito. The five republics number altogether forty five districts, each with a capital, and 253 towns and villages, exclusive of capitals. Costa Rica has 8 districts; San Salvador, 4; Honduras, 12; Guatemala, 13; and Nicaragua, 8; making in all, 45, while the population living within this area is not less than two million souls, or only 7 to the square mile of 640 acres, thus leaving an ample field for future development.

TRANSIT.

I shall now mention the various schemes of transit by canal, which have from time to time been proposed at and between Tehuantepec and Darien.

In little more than ten years after the first settlement was formed by Columbus, the Isthmus of Panama was successfully crossed by Vasco Nunez de Balboa (September, 1513), who, rushing up to his breast in the water of the Pacific, took possession of that mighty ocean in the name of his master, the King of Spain. From that period, the outline of the Pacific coast, both to the north and south, has been rapidly delineated on the charts, and a glance is sufficient to show how narrow a strip of land intervened at more than one point between the oceans. Then arose the desire to find a practicable route from sea to sea; and as commerce and colonization increased, doubtless every effort was made by the early conquerors and their followers to discover such an opening, but entirely without success as regards a water passage. In the town library at Nurembergh is preserved a globe made by John Schöner in 1520, on which a passage through the Isthmus of Darien is carefully delineated. Owing to the extraordinary jealousy of the mother country, but little has ever transpired as to the nature of the explorations made with a view to transit by the early conquerors; and the first authentic account of the nature of the overland passage from sea to sea was obtained from the buccaneers, from whom that most remarkable man, William Paterson, one of the founders of the Bank of England, gleaned the information which enabled him to propound a project which was the grandest conception, as it was the greatest national misfortune, of the seventeenth century. Paterson's noble project of opening a "highway of nations" was basely and treacherously ruined, and the idea was not revived until after the Spanish American colonies had thrown off the yoke of the mother country; then, indeed, a host of plans were formed for joining the two oceans.

TEHUANTEPEC.

Fernando Cortez was the first who gave his earnest attention to the search for a practicable route from sea to sea. In his admirable letter to the King of Spain, this passage occurs: "It is the thing above all others in this world I am desirous of meeting with, on account of the immense utility which I am convinced would result from it." Cortez appears to have concentrated his attention upon the isthmus at Tehuantepec, and so great was his confidence in the belief that at this part of Central America the problem would be solved, that he selected the lands in the vicinity as his portion of the conquered country.

After the death of Cortez, the idea of forming a passage from sea to sea, across the Isthmus of Tehuantepec, appears to have been abandoned; indeed, the jealousy and bigotry of the conquerers seems to have caused a reaction in favor of closing every avenue of approach to the New World, instead of opening new roads through it. The learned divine, P. d'Acosta, writing in 1588, says: "I am of opinion that no human power would be sufficient to cut through the strong and impenetrable bounds which God has put between the two oceans, of mountains and iron rocks, which can stand the fury of the raging seas; and, if ever possible, it would appear to me very just to fear the vengeance of heaven for attempting to improve the works which the Creator, in His Almighty will and providence, or-

dered from the creation of the world." It is not a little curious that exactly 200 years later (1788) another divine, the Cura of Darien, secured to himself the honor of making a water communication from sea to sea, at the southern extremity of Central America, by a shallow canal from the water of the Atrato to the head waters of the Nipipi, which empties itself into the Pacific. The ruins of the canal could be plainly traced some 30 years ago, when I was engaged in the survey of the Bay of Panama.

In 1814, the Spanish Cortes authorized the formation of a canal across the Isthmus of Tehuantepec in preference to Nicaragua or Panama. In 1842, the Provisional President of Mexico, Santa Anna, granted to Don José de Garay, the exclusive privilege of using steam locomotive power for transit across the isthmus, and that gentleman caused the most elaborate surveys of the route to be made; but the length of the line, the poorness of the ports at each extremity, and the distracted state of the country, combined to deter capitalists from embarking on such an undertaking, and consequently nothing has been attempted. Dampier, Don Augustin Cramer, and the great Baron von Humboldt, have at various times spoken in favorable terms of this route. The latter writes: "We cannot doubt that this point of the globe deserves no less attention than the Lake of Nicaragua."

A canal across the Isthmus of Tehuantepec would be at least 140 miles in length, the summit to overcome would be 656 feet, while the estimated cost reached nearly four millions sterling, and that without including the formation of harbors on either side; the actual sea approaches being mere roadsteads. The grants for opening a canal across Tehuantepec (1842) was the first concession of any Spanish American Republic for crossing the country.

NICARAGUA.

The Nicaraguan project has been upheld by many first-rate men, Baily, Stephens, Kelly, and others. In 1830, a company was formed in Holland, under the patronage of the King, for making the canal, but the disturbances in that country broke up the company. Again, in 1835, the project was brought before the Government of the United States, and a resolution of the Senate was passed in favor of it; but the agent sent by General Jackson, then President, to arrange with the Nicaraguan authorities, died on the road, and the matter was allowed to drop. No one, however, has taken so warm an interest in the subject as the late Emperor of the French. It appears that Don Francisco Castillon, envoy to the Court of France, put himself, in 1840, in communication with Prince Louis N. Bonaparte, at that time a prisoner at Ham, and proposed to him, in the name of the Nicaraguan Government, to take upon himself exclusively the construction of the proposed canal. After his escape from Ham and safe arrival in London, he devoted a considerable amount of time and study to it, and not only wrote a most able pamphlet, but publicly advocated the project at the Institution of Civil Engineers, in 1847.

I have made careful extracts from the valuable notes of the Emperor Napoleon III., and have no doubt that a reproduction of those extracts in this place will be agreeable to our members, and prove an addition to the pages of our *Journal* of no mean value, not only to its readers, but to the advantage of the Society itself. The extracts will be found further on.

In the years 1837 and 1838, a survey was made Mr. John Baily, lieutenant in the Royal Marines, at the request and under the authority of General Morazan, then President of the Central American Republic, for the purpose of ascertaining the practicability of forming a canal from the port of San Juan del Sur, on the Pacific Ocean, in lat. 11° 15′ N., long. 86° 1′ W. by the Lake of Nicaragua and the River San Juan, to the Atlantic.

The port of San Juan del Sur is narrow at the entrance, but widens within the harbor; it is surrounded by high land except from west-south-west to west-by-south; the depth of water at the entrance is three-fathoms, and its width 1,100 yards. Ships can go up for about half a mile, but as the winds often blow with great violence from the north and north-east, there is sometimes considerable difficulty in making the anchorage.

From this port Mr. Baily took a line of levels, not in a direct course, but diverging, so as to pass between the hills at the lowest point, when it could be done without widely deviating from a straight line, and in many places he passed through ravines of from 30 to 120 feet in depth. Mr. Baily found the ground rise, with a gradual acclivity, from the beach to the distance of 5,880 yards, where it attained a height of 284 feet, then for 904 yards it rose rapidly to the summit 615 feet above the level of the ocean.

The ground then descended rapidlly, and in a distance of 8,664 yards, the elevation was reduced 295 feet, whence it gradually sloped with but slight interruptions for a further distance of 6,168 yards, where it joined the River Lajas, along which it ran for 6,792 yards, and afterwards discharged itself into the Lake of Nicaragua. The surface of that lake was 128 feet 3 inches above the level of the sea; the whole distance from the South Sea to the lake, by Mr. Baily's track, being 28,408 yards, and his mean course N. 33° E.

The dimensions of the Lake of Nicaragua are variously given by different writers; but Mr. Baily seems to have taken some pains to ascertain them exactly, and he states the length to be 95 miles, the breadth in its widest part to be about 53 miles, and the average depth of water, according to his soundings, 15 fathoms. These dimensions agree with the map of Don Felipe Bouza.

The length of the river San Juan, with all its surroundings, from the lake to Grey Town, is 119 miles, with a fall of 107½ feet. There are four rapids, viz., Machula, Castillo Viejo, El Nuco, and del Toro, extending over about six miles, with broken water running over a rocky bottom. The San Juan is fed by many tributaries, the largest of which are San Carlos and Serapique, taking their rise in Costa Rica. The volume of water in the San Juan varies of course in different seasons; at the commencement of June, the lowest stage, about 12,000 cubic feet per second passed from the lake. The greatest rise in the lake ever known was six feet. At high lake, about October, there is probably about 40,000 and 50,000 cubic feet per second, divided at the delta of the river, of which about three-fourths pass out by the Colorado branch, and the remainder by the San Juan.

The whole length of the canal, from the Lake of Nicaragua to the Pacific, is fifteen miles and two-thirds. According to the plan, in the first eight miles, only one lock is necessary; in the next mile, sixty-four feet of lockage are required; in the next three miles there are about two miles of deep cutting, and one mile of tunnel, and then a descent of 200 feet in three miles by lockage to the Pacific.

Thus far of the canal across the isthmus.

The Lake of Nicaragua is navigable for ships of the largest class down to the mouth of the River San Juan (where it quits the lake). This river has a fall of one foot and six-sevenths per mile to the Atlantic. If the bed of the river cannot be cleared out, a communication can be made either by lock or dam, or by a canal along the bank of the river. The latter would be more expensive, but on account of the heavy floods of the rainy season it is preferable.

The total length of the canal from sea to sea would be little short of 200 miles, viz., 15½ from the Pacific to the lake, 56½ across the lake, and 119 to the Atlantic; total, 191 miles.

The estimate is:

From the lake to the west end of the tunnel.....	£1,500,000
Descent to the Pacific.....	500,000
From the Atlantic by canal along the river	2,500,000
	£4,500,000

DARIEN.

The remaining project takes one starting point, namely, the River Atrato, which is ascended for some distance and then quitted for one of its affluents, the Naipipi, or Truando, for example, whence it is proposed to cut a canal to Cupica Bay or Kelley's Inlet, near the Bay of Panama. Other projectors prefer continuing along the Atrato until its shalshallows are reached, and thence cutting a canal to the deep waters of the San Juan, which empties itself into the Pacific at Point Chirambira. This last was Humboldt's favorite project, and this is the point where the passage from sea to sea has been made, as described by

him in his "Travels." It appears that the Padre of the district, in 1788, induced his Indian converts to cut a trench between the head waters of the San Juan and the upper stream of the Atrato, through the ravine De la Raspadura, and that he actually passed from ocean to ocean in a canoe during the rainy season. The cut is about three miles in length, and has been neglected of late years; but I was informed by the Alcalde of the place, when I was surveying about Cupica in 1847, that he had himself paddled through the cut. The total distance from sea to sea, from the mouth of the San Juan to the mouth of the Atrato, is about 225 miles.

At a later date (1854–5), an American gentleman named Kelley, entered warmly into this matter, and spent large sums of money in regular surveys and explorations. As Mr. Kelley's efforts at canalization have been most systematically carried out, and his surveys and estimates contain some sound information, I insert a few extracts:

The line will proceed direct south from the Bay of Candelaria, up the Atrato to its junction with the Truando, lat. 7° 15′ N. and long. 77° 8′ 32″ W., a distance of 67 miles 1,436 yards, whence it will diverge by the Truando to the S.W. and terminate at Kelley's Inlet, lat. 6° 57′ 32″ N. and long 78° W., a distance of 63 miles 1,216 yards. It will thus have a total length of 131,892 yards from sand bar to sand bar, with a minimum width and depth throughout of 200 and 30 feet respectively.

The difference in the height of the tides at the two extremities of the proposed route has been ascertained to be, at the entrance of Kelley's Inlet in the Pacific, 12 feet 6 inches at spring tides, and 10 feet 11 inches at neap tides; while the tidal rise at the mouth of the Atrato never exceeds two feet at any phase of the moon.

Colonel Lloyd estimated the mean level of the Pacific at 3.52 feet above that of the Atlantic; and more recently, M. Garella fixed it at 9.54 feet. Now, from a series of careful observations made in 1855 by Colonel Totten, the engineer of the Panama railway, in Navy Bay on the Atlantic side, and the Bay of Panama on the Pacific, it results that the difference, if any, is exceedingly trifling. Colonel Totten says in his report: "Although my observations make the mean level of the Pacific from 0.14 to 0.75 feet higher than the mean level of the Atlantic, this is probably owing to local circumstances alone. I think I may therefore state that there is no difference between the mean levels of the two oceans."

GENERAL CONSIDERATIONS.

You have now before you an account of Central America in general outline, and the three several points of vantage across which canals have been proposed somewhat more in detail; it only remains to choose between the rival proposals.

If we are to have a Central American Canal at all, there seems no reason to doubt that the choice will fall upon Nicaragua, for the general consensus of opinion appears unmistakably to incline in that direction, and most certainly no valid reason has been given against the adoption of that route by any one practically acquainted with the locality; on the contrary, the Americans, who certainly are the best judges, have made up their minds that Nicaragua offers the best, if not the only practicable passage for a canal across the Isthmus.

The English, unquestionably, will in no shape attempt to thwart this decision; indeed, in my opinion, we should do well to accept the situation, with this proproviso only, that the Nicaraguan Canal must absolutely be neutral territory, open to all comers, entirely unrestricted as a "highway of nations"

As with Suez, so with Nicaragua; if English commerce did not pass along the canal, it could not be made to pay any dividend on the capital required, and, therefore, it would be indeed lamentable if our Government allowed Quixotic notions, such as prevailed in 1846 with regard to free trade, to influence them in allowing English money to gravitate towards paying for the construction of the Nicaraguan Canal, so far, at least, as they can stop it, without taking very good care to have a *quid pro quo*.

Until a proper understanding is arrived at with the United States, ensuring us against the possibility of finding, some fine day, when we are least prepared for such an emergency, that the Monroe doctrine has been brought into play

against English shipping, it will be politic to hold aloof from any participation in the undertaking. At the present moment, all the approaches to the Pacific are practically in the hands of the United States. In proof of this, it is only necessary to mention, that had it been necessary to telegraph to our squadron in the Pacific two years ago the sudden declaration of a war, that message would not have reached the British commander until his men-of-war had been captured in detail, and the capital of Vancouver's Island, with the munitions of war stored at Esquimalt bombarded and probably destroyed, to say nothing of the complete annihilation of our grain fleet, numbering not less than a thousand ships, freighted to convey to our shores the staff of life, amounting to nearly a million tons, not *quarters* of wheat. Surely, with such gigantic, if not vital consequences at stake, our Government will awake to the necessity of coming to a clear understanding with that of the United States before allowing the gate of the Pacific, now slammed in our face, to be also barred against us, in default of our intelligent participation in the enterprise of cutting a canal between the Atlantic and Pacific Oceans.

With regard to French interests, M. de Lesseps has made a mistake, which we may be sure, from the generous nature of his character, he will speedily rectify—he has simply followed a portion of the advice of my old friend, the far-famed Baron von Humboldt, in a letter to Mr. Kelley, of which I extract the following paragraph:

"The great object to be attained is, in my opinion, a canal which would unite the two oceans without locks and without tunnels. When the plans and sections can be placed before the public, a free and open discussion will elucidate the advantages and disadvantages of each locality; and the execution of this important work, which interests the civilized nations of the two continents, will be entrusted to engineers who have successfully distinguished themselves in similar enterprises."

M. de Lesseps is the last man to be discouraged by a failure; probably he already feels that he had better have relied on his own undoubted genius or followed up the proposals of his great and good patron, the late Emperor Napoleon III., whose wisdom and forethought are now conceded on all sides; indeed, I cannot do better than conclude this part of my subject by publishing, after long and close study, the views and opinions of that sagacious monarch on the Nicaragua Canal.

I quote from a very rare paper written by the late lamented Emperor; the extracts will, I am sure, find an honored place in the pages of the *Journal of the Society of Arts.*

EXTRACTS FROM A PAMPHLET WRITTEN IN 1847 BY NAPOLEON III.:

"There are certain countries which, from their geographical situation, are destined to a highly prosperous future. Wealth, power, every national advantage, flows into them, provided that where Nature has done her utmost, man does not neglect to avail himself of her beneficent assistance.

"Those countries are in the most favorable condition which are situated on the high-road of commerce, and which offer to commerce the safest ports and harbors, as well as the most profitable interchange of commodities. Such countries, finding in the intercourse of foreign trade illimitable resources, are enabled to take advantage of the fertility of their soil; and in this way a home trade springs up commensurate with the increase of mercantile traffic.

"It is by such means that Tyre and Carthage, Constantinople, Venice, Genoa, Amsterdam, Liverpool and London attained to such great prosperity, rising from the condition of poor hamlets to extensive and affluent commercial cities, and exhibiting to surrounding nations the astonishing spectacle of powerful States springing suddenly from unwholesome swamps and marshes.

"Venice, in particular, was indebted for her overwhelming grandeur to the geographical position which constituted her for centuries the *entrepôt* between Europe and the East; and it was only when the discovery of the Cape of Good Hope opened a ship passage to the latter that her prosperity gradually declined. Notwithstanding, so great was her accumulation of wealth, and consequent commercial influence, that she withstood

for three centuries the formidable competition thus created.

There exists another city famous in history, although now fallen from its pristine grandeur, so admirably situated as to excite the jealousy of all the great European powers, who combine to maintain in it a Government so far barbarous as to be incapable of taking advantage of the great resources bestowed on it by Nature. The geographical position of Constantinople is such as to render her the queen of the ancient world. Occupying, as she does, the central point between Europe, Asia and Africa, she could become the *entrepôt* of the commerce of all these countries, and obtain over them an immense preponderance, for in politics, as in strategy, a central position always commands the circumference.

"Situated between two seas, of which, like two great lakes, she commands the entrance, she could shut up in them, sheltered from the assaults of all other nations, the most formidable fleets, by which she could exercise dominion in the Mediterranean as well as in the Black Sea, thereby commanding the entrance of the Danube, which opens the way to Germany, as well as the sources of the Euphrates, which opens the road to the Indies, dictating her own terms to the commerce of Greece, France, Italy, Spain and Egypt. This is what the proud city of Constantine could be, and this is what she is not, because, as Montesquieu says, 'God permitted that Turks should exist on earth, a people the most fit to possess uselessly a great empire.'

"There exists in the New World a State as admirably situated as Constantinople, and we must say, up to the present time, as uselessly occupied; we allude to the State of Nicaragua. As Constantinople is the center of the ancient world, so is the town of Leon, or rather Masaya, the center of the new; and if the tongue of land which separates its two lakes from the Pacific Ocean were cut through, she would command, by her central position, the entire coast of North and South America. Like Constantinope, Masaya is situated between two extensive natural harbors, capable of giving shelter to the largest fleets safe from attack. The State of Nicaragua can become, better than Constantinople, the necessary route for the great commerce of the world; for it is for the United States the shortest road to China and the East Indies; and for England and the rest of Europe, to New Holland, Polynesia, and the whole of the Western Coast of America.

"The State of Nicaragua is, then, destined to attain to an extraordinary degree of prosperity and grandeur, for that which renders its political position more advantageous than that of Constantinople, is that the great maritime powers of Europe would witness with great pleasure, and not with jealousy, its attainment of a station no less favorable to its individual interests than to the commerce of the world.

"France, England, Holland, Russia, and the United States, have a great commercial interest in the establishment of a communication between the two oceans; but England has more than the other powers a political interest in the execution of this project. England will see with pleasure Central America becoming a flourishing and powerful State, which will establish a balance of power by creating Spanish America a new center of active enterprise, powerful enough to give rise to a great feeling of nationality, and to prevent, by backing Mexico, any further encroachment from the north. England will witness with satisfaction the opening of a route which will enable her to communicate more speedily with Oregon, China, and her possessions in New Holland. She will find, in a word, that the advancement of Central America will renovate the declining commerce of Jamaica and the other English islands in the Antilles, the progressive decay of which will be thereby stopped.

"It is a happy coincidence that the political and commercial prosperity of the State of Nicaragua is closely connected with the policy of that nation which has the greatest preponderance on the sea."

In the remainder of his pamphlet, after fully considering the cost of the land, the Emperor enters at length upon his plan for combining colonization with the canal undertaking. The main features of this plan are well worthy the most careful consideration, and are here produced:

"We have stated that the secondary

profits of the canal would arise from the increase in the value of the soil. According to our information, the Government of Nicaragua would cede to the company all the land lying on the right and left banks of the canal throughout its entire course, to an extent of two leagues inland, forming three hundred square leagues, or about 1,200,000 acres. These 1,200,000 acres are at the present moment worth 1s. 6d. per acre. The proposed gift by the Government of Nicaragua to the company is, therefore, now of the value of £90,000. If we deduct from the above number 200,000 as probably incapable of cultivation, and 300,000 more that would be required for the service of the company, producing no income, or as concessions to its engineers, servants, etc., there will remain 700,000 acres to explore and improve. The canal being accomplished, it will be easily granted that these lands may in all probability bear a value of £2 per acre.

"£2 per acre. Let us put it at £1 per acre only, and we shall have a property of £700,000 vested absolutely in the company, for we must not forget that the soil is here very fertile; that they frequently have more than two harvests a year; that the indigo produced in this country is better than that produced in the East Indies; that the tobacco is as good as that at Bavaria; that coffee and sugar are easily produced; that the forests are filled with Brazil wood; that there are mines to work; and, finally, that the waste water thrown off the canal works would afford power for manufacturing purposes. It is thus evident that if the company should limit itself to the disposal of these lands when the canal is complete, they would derive great profit were it only by the increase of value; but, in our opinion, there is a greater advantage to be derived from their detention.

"We firmly believe that it is important to continue, with the construction of the canal, the project of colonization, in order that the two undertakings should assist each other, and to enlist as share holders the large mass of emigrants who annually depart for America, and who, according to the statistical information gathered up to this day, set forth with an average sum per head of £20.* Thus the shares would be placed in hands most interested in the success of the undertaking; for those who join an enterprise for the sake of investment, and not mere gamblers, ensure the solidity of an undertaking.

"The capital of £4,000,000, which we presume to be necessary for the construction of the canal, should be divided into 400,000 shares of £10 each. By paying down the value of one or more shares, the emigrant shareholder would be entitled on his arrival in America, to such accommodations as would enable him to overcome the first difficulties necessarily attendant on early steps in colonization. Every emigrant shareholder would receive from the company twenty acres of land to cultivate, as well as the implements necessary for that purpose.

"The 700,000 acres of land would be thus distributed among 35,000 emigrants, and sold to them on the following terms: Ten years' time would be allowed for the emigrant shareholder to pay the company the price of the twenty acres allotted to him, as well as the outlay incurred by the company in procuring him dwelling, food, and all the accommodations required. The payments should be made by annual instalments, and proportionate to the progressive increase of value likely to increase every year in the property.

"So the whole of the first year having been entirely taken up by preparing and tilling the ground, the emigrant shareholder should not be made liable for any payment whatever during that time. The annual instalment should begin to be paid off at the end of the second year, and accomplished in the progressive manner indicated in the following table:

* We read in the *Journal des Débats*, of the 3rd May, 1846, that the society formed at New York, the 31st of March, 1784, to assist the indigent Germans in the United States, had just celebrated the sixty-second anniversary of its foundation. On this occasion they have published a pamphlet which states, amongst other things, that the number of German emigrants which arrived during the last year in the city of New York alone amounted to 30,567, each of them having an average sum of £20 sterling. Of these emigrants 12,225 arrived from Havre in seventy-eight ships; 9,647 from Bremen in seventy seven ships; 3,718 from Antwerp in twenty-five ships; 2,525 from Hamburg in twenty-four ships; 1,959 from Rotterdam in thirteen ships; 493 from Ghent, London and Liverpool, in five ships. The greater part took their direction towards the Southern States. In 1814, there arrived only 17,999 German emigrants at New York.

	Per Acre. Per Annum.		
At the end of the first year	£0	0	0
" " second year	0	1	0
" " third year	0	1	6
" " fourth year	0	2	0
" " fifth year	0	2	6
" " sixth year	0	3	0
" " seventh year	0	3	6
" " eighth year	0	4	0
" " ninth year	0	4	6
" " tenth year	0	5	0
" " eleventh year	0	5	6
	£1	12	6

So every acre of land will procure to the company, in the course of eleven years, a net profit of £1. 12s. 6d., and, consequently, 700,000 acres of land will bring, in the above-stated lapse of time, the corresponding profit of £1,137,500.

"The company would establish as many villages as would be necessary for the number of colonists. Each village would be erected on the most healthy spots, and in the vicinity of a river. It would be composed of 200 dwellings, each dwelling being appropriated to one family. A village would then cost:

200 dwellings at £4 each	£800
Maintenance for the first six months, and seed, at £4 per family	800
Church, stores and schools	280
Casual expenses	120
	£2,000

"If we divide this sum by the number of families, we shall find that the outlay will be £10 per family, in ten years to be reimbursed as above stated. Now, let us suppose that in about ten years the company has established 175 villages containing 35,000 families; the expense will have been £350,000, which the company will be reimbursed by the annual progressive rate. As each of these families have been enabled to buy and pay for twenty acres of land, at the progressive rate above mentioned, the company will have received for 700,000 acres the sum of £1,137,500, from which, deducting £350,000, the outlay for the construction of the villages, there will remain a clear profit of £787,500, exclusive of the interest received on the outlays. We must also remark that the colonists being shareholders, will have paid £767,500 to themselves in their capacity as a company; then there would be a perfect amalgamation of interests between the shareholders and the colonists, who would be equally interested in the success of the undertaking. Thus deducting the sum from the amount of £4,000,000 necessary for the construction of a canal, the capital expended would be about £3,200,000 only, bringing a net profit of £600,000, or ten per cent. per annum.

"At present, when the colonist goes to America, he finds no dwelling, no advance of capital, and often no employment; on our plan, on the contrary, by means of a share, he is sure to find, on arriving in America, a wholesome dwelling, livelihood for six months, fertile lands, and a community already settled. Moreover, a part of the money paid for the purchase of his land would come back to him as a shareholder, and in about ten years his property would not only be freed from all burdens, but he might expect at that period that both his share in the canal and his land would be doubled in value.

"Thus our project protects all interests; the capitalists realize large profits, and the emigrants partake of the benefits with a moral certainty of future prosperity. This neglected country speedily changes to florishing towns, its lakes are covered with fleets, and its wealth is increased by the progress of agriculture and commerce.

"Central America can emerge from her present languor only by following the example of the United States, namely, by borrowing from Europe labor and capital for this their first object. Independent of the advantages of its geographical position and of the fertility of its soil, the State of Nicaragua presents to European emigrants advantages which are not to be found in the United States. In the North of America, the population settled itself in the beginning on the Eastern coast, gradually extending inland. As long as the uncultivated lands were not far from the sea, the European emigrants easily found employment; but now the case is altered, and the great number of foreigners that daily arrive in the United States become for the following reason a burden to the nation. The uncultivated lands, where adventurers may easily find employment, are three hundred leagues from the coast, and as in most instances the emigrants are desti-

tute of means to reach those remote districts, they become in the towns on the coast a prey to indolence and misery.

"In Central America the reverse would be the case; the indigenous population has settled by preference on the coast of the Pacific Ocean, deserting all that part situated opposite the ancient world, so that when the country is in a position to require colonists and European laborers, they may arrive, through the canal, to places already inhabited, and the population will gradually extend from the west to the east, and not, as in the United States, from the east to the west, thus getting nearer to Europe in proportion as it increases, and offering facilities to the new colonists. till they reach the extreme borders of the country.

"The prosperity of Central America is connected with the interests of civilization at large, and the best means to promote the welfare of humanity is to knock down the barriers which separate men, races and nations. This course is pointed out to us by the Christian religion, as well as by the efforts of those great men who have at intervals appeared in the world. The Christian faith teaches us that we are all brothers, and that in the eye of God the slave is equal to the master, as the Asiatic, the African, and the Indian are alike equal to the Europeans. On the other hand, the great men of the world have by their wars comingled the various races of the world, and left them some of those imperishable monuments which, in leveling mountains, opening forests and canalizing rivers, has a tendency to upset these obstacles which divide mankind, and to unite men in communities, communities in people, people in nations. War and commerce have civilized the world. The time for war is gone by; commerce alone pushes its conquests. Let us, then, open to it a new route; let us approximate the people of Oceania and Australia to Europe; and let us make them partakers of the blessings of Christianity and civilization. To accomplish this great undertaking, we make an appeal to all religious and intelligent men, for this enterprise is worthy of their zeal and sympathy. We invoke the assistance of all statesmen, because every nation is interested in the establishment of new and easy communication between the eastern and western parts of the globe. Finally, we call upon capitalists, because whilst they are promoting a glorious undertaking, they are sure to derive a large profit thereby."

PART III.

PERSONAL EXPLANATION.

BEFORE proceeding to place before you the views and opinions which I entertain in respect to cutting a canal across Central America, it is only right that I should indicate the range of my experience, and show cause for the confidence with which I express those views and opinions.

In this respect, I cannot do better than quote from my printed address to the Paris Congress, which I was unable to attend, owing to a severe accident, breaking the left knee-cap, which literally tied me, at that time, by the leg:

"I may say that between the years 1845 and 1851 I was engaged, 'on and off,' on the surveys of the coast line of the Pacific Ocean, from Cape Corrientes to the port of Realejo, especially in and around the Bay of Panama—a coast of about 1,000 miles—my attention being particularly directed to the Gulf of San Miguel, the approaches of the Nippi, to the Chepo, or Bayano river, a route having the recommendation of possessing a waterway approaching the Atlantic Ocean nearer than any other, and to the magnificent harbor of Realejo in Nicaragua.

"On the Atlantic coast I have had an equal, if not more extensive, experience.

"Between 1859 and 1861 I was stationed as senior naval officer between Cape Gracios a Dios and Colon, or Aspinwall, and since that time I have often crossed Central America. I have been no less than six times through Nicaragua, and possess an accurate section with the theodolite between the Atlantic and the Lake of Nicaragua, on a line parallel to and about 40 miles distant from the river San Juan.

[That section you will see on the wall behind me.]

"I have pointed out fully in my works,

'The Gate of the Pacific, 1863,' and 'Dottings by the Roadside, 1869,' and this meeting is of course aware that there are still other routes to the northward; such as that through Tehuantepec and Honduras, for which latter State I was for some time Special Commissioner, and for more than a year devoted my best attention towards completing the Inter-Oceanic Railway; but circumstances over which I had no control prevented me from achieving that object. I am bound to say, however, that I still have faith in it, and believe the Government of the country would satisfy the just claims of their creditors to the last dollar, if only those creditors would bring a gentle pressure to bear, and insist upon payment, if not in money, then in land, in exchange for their bonds."

POLITICAL.

There is a phase of the question before us to-night which must not on any account be neglected, for, after all, it has quite as important a bearing as the physical geography, *plus* the engineering considerations of the enterprise, both put together; I mean the political or diplomatic aspect of the situation. We have now to ask ourselves how far the enterprise of effecting a junction between the Atlantic and Pacific, by means of a canal capable of transporting ships from one ocean to the other, across the Isthmus of Central America, may affect the political relations of the great nations affected by it.

To arrive at a solution of this problem, I must first point out the nature of interest which each of the nations named seems to possess in the proposed enterprise.

In the order of interest I have already adopted, I may point out—1. That a canal across Central America would be the gate of the Pacific to the United States, a gate, moreover, which no American statesman would allow for one moment to be in the governmental keeping of any other country whatever. 2. That England's concern in the undertaking is chiefly to further a supply of cheap grain from California: last year no less than a thousand sailing vessels, averaging 1,000 tons each, rounded Cape Horn, bound for England with a cargo of the "staff of life," and it is obvious that by shortening the passage and avoiding Cape Horn, freights and insurance would rule less, and consequently grain could be placed in the English market at a lower price.

At the same time it may be as well to warn the United States that in this case England's necessity would not be their opportunity, for there are other places besides California from whence we may draw a supply of grain, with far more ease and certainty, and at considerably less cost. The Euphrates Valley, for instance, which in ancient times was the granary of the world, and which England, by merely lifting up her little finger, could, within a very short time, restore to its pristine importance, and that not only in British interests, as a great field for British colonists, but eminently in furtherance of her duty, under the secret treaty, by advancing the prosperity and civilization of Asia Minor.

But taking a broad view of the position, it is quite in accordance with the best interests of the United States to join hand and glove with England in the canalization of Central America; at all events, without the co-operation of English capital and trade, this is certain, the canal would not prove a paying concern to the United States; indeed, it would take very much the character of a white elephant.

With regard to France, the canal is more a matter of sentiment than a real want, and in point of fact the French people for the next century can afford to remain in blissful ignorance, whether a canal across Central America exists or not. Nevertheless, the proposed work is of a nature to command the respect if not the enthusiasm of the French people, and, therefore, taking all the *pros* and *cons* into consideration, it may be quite worth the while of France to join with England and America in a sort of co-partnership to make the proposed canal a grand international work. The cordial union of the three nations is very desirable upon every ground, but how is this to be effected? By treaty? Certainly not; for treaties, now-a-days, are only made to be broken.

How, then, can this union be made? Why, in a business-like manner, for business purposes. Let the three nations join hands and become partners for the purpose of carrying out this grand un-

dertaking, and let the three nations weld themselves into one, as it were, by each undertaking a guarantee of 1 per cent. on the capital required.

The requisite money, no matter what the amount, would then readily be raised at 3 per cent., under a joint guarantee of the greatest nations in the world.

ADMIRAL AMMEN, U.S.N.

Before placing before you the suggestions I have to offer, it is only fair that I should inform you of the views of the American Government in respect to the Interoceanic Transit, as laid down by Admiral Ammen, at Paris, in May last.

In his address to the Congress, he clearly and unmistakably points to Nicaragua as having the preference, after exhaustive surveys, overy other part of the Isthmus of Central America.

The facts and figures mentioned by Rear-Admiral Ammen are conclusive, as will be seen by the following summary of the information which he gave to the Congress:

Extracts from the Address of Rear-Admiral Daniel Ammen, U. S. Navy, Vice-President of the Congress, Member of the Inter-Oceanic Canal Commission, appointed by H. E. the President of the United States, in compliance with a resolution of the Congress of the United States of America.

NICARAGUA ROUTE.

The rainfall is comparatively small. Our observations at Lake Nicaragua, extending over one year, show an annual rainfall of forty-eight inches, or 1.22 meters. There is a distinct dry season of between five and six months, when work in progress would not be delayed or injured, and but little interruption need be apprehended in the rainy season on that section of canal between the lake and the Pacific, as the rain generally falls at night, with occasional showers during the day.

There is abundant good stone, hydraulic and other lime, wood, and bamboos, which may be found very advantageous in the construction of harbors.

There is a considerable population, well disposed, and when they can have remunerative employment, fairly industrious. The country has an abundant cattle supply of good quality for food, and other productions which would furnish the main subsistence for laborers on the canal, with a convenient water transportation in general along the line of ship canal as located, and lake communication with an extensive, populated and fertile region. This water communication can be greatly increased, by the construction of a six-foot canal to Lake Managua, at an inconsiderable cost, and when completed would make the supplies of all kinds superabundant. Between Lake Nicaragua and the Pacific, near the line of the projected canal, several passable roads exist, and whatever other roads might be required over this short distance could readily be made at inconsiderable cost.

There is an inexhaustible water supply in its lake of 2,800 miles of superfice, which equalizes floods and makes the daily changes small in the discharge.

It has an excellent harbor on the Pacific coast at San Juan del Sur, convenient for anchorage as Brito itself would be improved as a harbor, inasmuch as the vessel in transit would have time to regulate her steam and be pointed fair to enter the canal at any assigned time. This reduces the necessity of a harbor at Brito to simply securing a perfectly smooth entrance to the canal.

Lake Nicaragua affords every facility for an interchange of cargoes that may be desired.

The west coast and the valley of the lake are, as compared with the eastern slope, comparatively healthy, and upon the eastern slope a considerable part of the labor can be done by means of dredging machines.

The approaches to both entrances are superior in advantages to those of either of the two other two routes with which the Nicaragua route is compared.

These considerations would seem to warrant the belief that cost of construction, including material, would be far less than upon either of the two other routes compared, as will be more fully shown hereafter.

PANAMA ROUTE.

The mean annual rainfall at Aspinwall in a series of seven years is found to be 124.25 inches, or 3.15 meters. A dry season exists, but it is limited to two or

three months, lessening the effective time for labor and of comparative healthfulness of the laborers employed, the wet being the sickly season.

No building material suitable is known in that region. The ties and railroad telegraph poles on the Panama Railroad are brought from Carthagena or elsewhere.

The population is inferior to Nicaragua in ability to furnish subsistence for a large number of laborers.

By means of the railroad already constructed, a canal under construction would have a convenient transportation at whatever cost might be agreed upon.

The cost of the feeder and adjuncts, as well as other disadvantages, notwithstanding the shortness of the line, as shown by maps, plans and estimates, make a total of $94,511,360, as against those of the Nicaragua route of $65,722,137 on a common basis of cost of material and labor, when in Nicaragua the material is near at hand and subsistence abundant, and on the Panama route, or in its region, there is no material for construction, inferior subsistence and less favorable climatic conditions for labor, as before stated.

DARIEN ROUTE.

Although the mean annual rainfall is not known, there is no doubt of the fact that it is largely in excess of the rainfall in Aspinwall, on the Panama route. There is only a nominal dry season, as at any time a precipitation of several inches is likely to occur, and actually does occur many times yearly during the so-called "dry season."

The building material supposed to be available is confined to wood.

The population is so scant as to be unable to furnish either assistance or subsistence for even an inconsiderable number of laborers.

The River Atrato would furnish transportation to the mouth of the River Napipi. Along the line of the projected canal the country is alternately rough and covered with swamps, so that great labor would be necessary to construct roads to secure even wagon transportation, for subsistence, and material for construction.

Under such conditions the projected feeders requisite would be made at great additional cost, as well as the projected tunnel and locks. In dimensions the projected tunnel is as follows: Length, 5,633 meters; height, 35.96 meters; width, 18.29 meters.

On the Atlantic slope there are twelve projected locks of 3.14 meters lift, and on the Pacific slope ten of 4.54 meters lift, the summit level being 43.59 meters above mean tide.

With the view of having a definite comparison, the estimate for material and labor, so far as they are identical, were made on a common basis with Nicaragua. The cost of this basis is given as $98,196,894, but it is quite apparent that with the lack of material convenient, of subsistence and transportation, as well as the absence of a dry season, and, above all, the impossibility of making even an approximate estimate of the cost of a tunnel under such conditions, that the actual cost of the execution of the work would be far in excess of the estimate.

The same physical conditions—the absence of a dry season and a general lack of material for construction, except wood, and the lack of subsistence—were found to exist by all our parties at various times on what is known properly as the Isthmus of Darien and of all the region lying south of it.

It is impossible not to be struck with the common sense of these remarks of Admiral Ammen. I know the Napipi, I know Panama, and I know Nicaragua, and I cordially indorse the American preference for the latter.

SUGGESTIONS.

I have now to offer a few suggestions, and propose a plan by which I hope to aid those who will embark in the enterprise of constructing a canal, through Nicaragua, from the Atlantic to the Pacific.

The great difficulty to be overcome in the construction of a canal across Nicaragua is the making and maintaining the harbor of Greytown, on its Atlantic terminus. My friend, the late Mr. Robert Stephenson, the great engineer, when I was with him in Egypt in 1858, used to say that he was acquainted with the deltas of all the great rivers of the world, but that he was not aware of a single instance in which a harbor was main-

tained at the mouth of any of such rivers. Now, the River San Juan de Nicaragua has a delta at its mouth, but no other delta in the world is so capricious. In 1856, a squadron of H.M.'s ships rode securely at anchor in the harbor of Greytown; but in 1860, when I was stationed as senior naval officer in that locality, the sand bar, which made the harbor, stretched across very nearly from shore to shore, leaving only sufficient depth of water for the very smallest coasting craft. A few years later there was again a considerable opening, and so matters went on, but now for some time it has been completely closed. A strong norther is sufficient to shut up the harbor, while a high river will re-open an entrance. Mr. Robert Stephenson's dictum, therefore, as to the enormous difficulties to be encountered in the attempt to form a harbor at the delta of any great river, is more than borne out in the case of Greytown.

I am well aware that an exception has occurred to this ruling in the case of the Mississippi, where Mr. Eads has succeeded in obtaining a depth of twenty-seven feet, under high pressure from Congress; but the problem is, how to maintain that depth at anything like a paying cost. If the engineering difficulties could be overcome, in forming and maintaining a harbor at Greytown, the other obstacles to the opening of the canal from ocean to ocean would be found of secondary importance, although it cannot be denied that the River San Juan is more or less encumbered with shoals and rapids, and with sudden rises in the rainy season of from 20 to 40 feet, making the control difficult; but to my mind Greytown itself would alone completely swamp the enterprise. Under these circumstances it seems desirable to suggest an alternative route, with very different dimensions for the canal, and a consequent diminution of cost from that at present contemplated.

Starting from Monkey Point, now called Pim's Bay, on the Atlantic, 40 miles north from Greytown, I should commence by cutting a canal from the inner part of that bay down to the Rama river, a distance of about 10 miles. The Rama river itself carries deep water about twenty miles into the interior; the remaining seventy miles to the Lake of Nicaragua would traverse land, offering no particular difficulty, as may be seen by the section which is suspended behind me.

From San Miguelto, on the Lake Nicaragua, by way of Tipitapa, to the northern shores of Lake Managua, there is nothing which an engineer would consider a difficulty in these days. The remainder of the canal to the *embarcadero* of Port Realejo, on the Pacific, can scarcely be said to afford a field for engineering skill, the great difficulty being the supply of water for the canal, but, inasmuch as lake Managua is higher than the Pacific, this is not insurmountable. The distances by this route would be as follows:

	Miles.
Pim's Bay to Lake of Nicaragua..	100
Lake Navigation....	85
Rio Panaloya or Tipitapa.....	20
Lake Managua.....	40
Lake to Realejo....	45
	290

occupying, at four miles an hour, say, three days.

I must point out that, in this scheme, a deep-water canal is not even contemplated; a depth of eight feet would be amply sufficient, the vessels being raised and transported on pontoons by the process which has been successfully used in the Victoria Docks for years. A ship of the largest tonnage is raised within half an hour, and the pontoon, only drawing four feet of water, is hauled, with the ship securely resting upon it, into a shallow dock for its reception. It is needless to say how considerably the cost of the canal works would be reduced if such a plan were adopted, while there are other advantages, such as cleaning the ship's bottom *in transitu*, just as if she were in dock, the doing of which would effect a saving to the owners, by increase of speed, almost, if not quite sufficient, to pay the canal dues.

Another suggestion I wish to make is this: first open in the proposed direction a complete transit from Pim's Bay to Realejo by means of a railroad and lake steamers. It must be apparent how materially this would cheapen the canal works, if only by enabling the engineers to avoid many an obstacle which, without such a pilot, would be sure to crop up and impede the works. Besides, such a

transit would, I have reason to believe, earn enough to pay interest on the canal capital within a year of its construction, and I believe that the works of the railroad, a light single line, might be finished in about a year after turning the first turf. The advantages to be gained by adopting the plan I have just proposed seem to me obvious; but I will go even farther, and suggest that this railroad, from Pim's Bay to the Lake of Nicaragua, should be built, even if the canalization of the River San Juan is determined upon, because then the engineers could be supplied with all their requirements with the stream instead of against it.

An estimate is always a delicate matter to deal with, and I shall not attempt to go into detail, but take the outside sum of £20,000 a mile, and the outside length of my proposed route at 300 miles, upon nearly one-half of which distance no outlay will be needed, so that, practically, my estimate is £40,000 a mile; the total sum required would then amount to six millions as the outside cost of a water communication from ocean to ocean, including the pilot transit I have already mentioned.

I do not believe there would be any difficulty in raising six millions sterling in America, England and France, for such purposes, if only a land warrant for a five acre plot were given as a bonus with each £10 share. This would necessitate a grant of land with the concession of some 5,000 square miles on each side of the Canal of Nicaraguan territory, between the Atlantic and the Lake of Nicaragua, and would, no doubt, be readily given. But I think it will be admitted by everybody, that such a work as joining the Atlantic and Pacific Oceans should not be left to private enterprise. It is surely a work of sufficient magnitude to enlist international support, especially if that support can be shown to require a pecuniary outlay only of the smallest dimensions, and that only for two or three years.

Let us assume the capital to be, as I said just now, six millions. Now, if England, America and France would join hands, and each guarantee 1 per cent. on that amount, we should have a joint guarantee of 3 per cent.—inducement sufficient for English investors alone to take up the whole sum in less than a week. What is 1 per cent. on £6,000,000? £60,000 a year—a sum, I venture to think, annually wasted on any vote exceeding one million of the Navy estimates. And what do we get for our money? Why, at the least, a consolidation of the friendly feeling between this country, the United States and France, far more lasting and binding than could be effected by any treaty merely guaranteeing the neutrality of the route. We should be joint proprietors of the canal, and that, in my judgment, is the only safe arrangement to be made, considering the tremendous stake involved.

CONCLUSION.

In the preceding remarks, I have endeavored to place before you a bird's-eye view of the efforts which have been made, notably by the Paris Congress, to resuscitate the project of cutting a canal across the Isthmus of Central America; I have also tried to give you a general idea of Central America itself, and the various proposals made to effect a junction across it: and I have pointed out why the isthmus at Nicaragua is more favorable for the construction of a canal than at Panama; finally submitting to you my own plans and proposals based upon long practical experience on the spot. At last the day appears to have arrived, for which I have worked hard for twenty years at no mean expenditure of time and money.

If the Government is blind to British interests and has lost that spirit of enterprise through which our forefathers raised the nation to its present greatness; if the Government neglect to take up a proper position towards a project so closely interwoven with the future of the United Kingdom, then such degeneracy must be deplored, and theirs is the responsibility.

My interest in Nicaragua, or rather Mosquito, is as great as ever; I still own considerable property there, many thousand acres of land, and the freehold of the Atlantic Terminus at Pim's Bay, but I say now to the present Government, as I wrote to that of 1859, and recorded in my book, "The Gate of the Pacific," published in 1863, that I simply hold this property in trust for the national benefit, and my great ambition is that it may prove useful to further the prestige and maintain the power of old England.

THE MEASUREMENT OF EARTHWORK BY THE PRISMOIDAL FORMULA.

By C. P. AYLEN, B. C. E.

Written for VAN NOSTRAND'S MAGAZINE.

IN the application of the prismoidal formula to the measurement of earthwork the deduction of the mid-section requires more care than it generally receives. The usual method is to take the means of the heights and widths of corresponding cuttings in the end sections for heights and widths of points in the mid-section. In this manner the mid-area is easily computed. The results thus obtained are perfectly correct in level ground, and even in rough ground, results sufficiently accurate for practical purposes may be obtained by close cross-sectioning, though at considerable sacrifice of labor. A general method of computation may be easily derived from the general formula, which will satisfy all cases likely to occur in practice, and give results which, in theory at least, are mathematically correct. Let the volume of an earthwork prismoid, consisting of one station of a railroad excavation, be required. Let the center height of one end above the intersection of the side slopes be h_0; other heights to the right of the center line, h_2, h_4, h_6, &c.; and their respective distances out, d_2, d_4, d_6, &c. Let h'_0 be the center height of the other end section, h'_2, h'_4, h'_6, &c., heights, and d'_2, d'_4, d'_6, &c,, their respective distances out to the right; h'_1, h'_3, h'_5, &c., heights, and d'_1, d'_3, d'_5, &c., their respective distances out to the left. Let 1′, 3′, 3, &c., denote the points whose heights are h'_1, h'_3, h_3, &c., and whose distances out are d'_1, d'_3, d_3, &c., respectively. If 1′, 3′, 3, is one of the surface planes of the prismoid, and if vertical planes are passed through 31′ and 33′ to the side slopes, we have a wedge-shaped solid whose end area is

$$\tfrac{1}{2}(d'_3-d'_1)\,[h'_1+h'_3-\tfrac{1}{s}(d'_3+d_1)],$$

and whose mid-area is:

$$\tfrac{1}{8}(d'_3-d'_1)[h'_3+2\,h_3+h'_1 -\tfrac{1}{s}(d'_3+2d_3+d'_1)]$$

where s is the tangent of the angle which the side slopes make with the vertical. Consequently the mean area is, by the prismoidal formula,

$$\mathrm{M}=\tfrac{1}{6}(d'_3-d'_1)[h'_3+h_3+h'_1 -\tfrac{1}{s}(d'_3+d_3+d'_1)] \quad . \quad . \quad . \quad (\mathrm{A})$$

The mean areas of the wedge-shaped bodies beneath the outer surface planes are found in a similar manner. Their sum, minus the area of the grade triangle, is the mean area of the whole prismoid, which, multiplied by its length, gives its volume. It will be noticed that by this method not only the end-sections, but also the distribution of the surface planes must be known, otherwise it is difficult to see how the prismoidal formula, or any other formula, can give correct results. If the arrangement of the surface planes is not given, the form of the solid is not known, and consequently its volume cannot be determined. When the work is partly in excavation and partly in embankment, the formula must be slightly modified. The intersection of grade with the surface of the ground should be determined in the field. If a vertical plane is passed through this intersection—extending downward to the slope of the excavation and upward to the slope of the embankment, we have two prismoids, one containing the excavation, and the other the embankment. The mean areas of the portions above or below the surface planes are found as before, except that we must put

$$\mathrm{M}=\tfrac{1}{6}(d_3'-d_1') [h_3'+h_3+h_1'+\tfrac{1}{s}(d_3'+d_3+d_1')] \ldots (\mathrm{B})$$

when the plane 33′1′ lies between the center line and grade. From the mean area of each of these prismoids the mean area of its respective grade prismoid must be subtracted. If g is the center height of grade above the side slope, δ and δ' the distances out of the intersec-

tion of grade with the surface, the mean area of the grade prismoid is

$$\tfrac{1}{6}s[(g\pm\tfrac{1}{s}\delta)^2+(g\pm\tfrac{1}{s}\delta)(g\pm\tfrac{1}{s}\delta')+(g\pm\tfrac{1}{s}\delta')^2] \quad . \quad . \quad . \quad (C)$$

The positive sign is used when the cut or bank extends beyond, and the negative when it does not reach the center line. Here follows two simple examples, which will show the application of the principles enunciated.

Example I. $s=\frac{3}{2}$, half width of roadway, 9 feet, length 100 feet, and other data as tabulated.

Station From	Station To	Subscript.	h.	h'.	d	d'	Surface Plane.	$3g+eh$	$\frac{1}{s}ed$	Diff.	Diff. in width.	6 M to slopes.	M to slopes.	M to grade.	Cu. Yds.
0	1	0	8	13.6	0	0	0'20	51.6	18	33.6	27	907.2			
		2	12	10	27	24	22'0	53.6	34	19.6	24	470.4			
		1	4	8	15	21	01'0'	47.6	14	33.6	21	905.6			
							1'10	38.0	24	14	15	210.0	382.2	328.2	1215.6

The first eight columns contain the data. The first two need no explanation, the third contains the subscripts of the letters in the next four columns; for instance, h_2' is found opposite 2 in the column headed h', with the difference that heights are here measured from grade instead of from the intersection of the side slopes, three times the height of the grade triangle being added to the sum of the heights. The eighth column gives the surface planes.

Example II. Partly in excavation and partly in embankment. In excavation, half width of road-bed, 11 feet, $s=1$; in embankment, half width of road-bed, 9 feet, $s=1\frac{1}{2}$, length 100 feet; other data as tabulated.

Station. From	Station. To	Subscript.	h	h'	d	d'	Surface Plane.	$3g+eh$	$\frac{1}{s}ed$	Sum or difference.	Difference of widths.	6 M to slopes. Cut.	6 M to slopes. B'k	M to slopes. Cut.	M to slopes. B'k	M area of grade prismoid. Cut.	M area of grade prismoid. B'k	Mean area. Cut.	Mean area. B'k	Cu. yards. Cut.	Cu. yards. B'k
0	1	2	6	5	17	16	0'20	44	17	27	17	959									
		0	2	3	0	0	22'0'	47	33	14	16	224									
		1	0	0	4	3	01'0'	38	3	41	3	123									
		3	−4	−2	15	12	1'10	35	7	42	4	168		162.3		105.2		57.2		211.7	
							3'31	−24	20.7	3.3	11		36.7								
							13'1'	−20	12.7	7.3	9		66		17.1	1	10.1		70		25.9

In this example the minus sign is used to distinguish quantities in embankment from similar ones in excavation; having no algebraic significance it is not used beyond the ninth column, where it is useful in separating the part in excavation from that in embankment.

It is sometimes desirable to know the position of the center of gravity of a portion of earthwork. In that case the following theorem may prove useful:

If A_1 and A_3 are the bases, A_2 the mid-area and l the length of a prismoid, the distance of its center of gravity from A_1 is

$$u=\frac{o.A_1+1.4A_2+2A_3}{A_1+4A_2+A_3}\,\frac{l}{2}$$

From this it follows that if A_1, A_2 A_3, are equidistant cross-sections of an excavation or embankment, A_2, A_3, interpolated mid-areas, and l its length, the distance of its center of gravity from A_1 is

$$u=\frac{o.A_1+1.4A_2+2.2A_3+3.4A_4+4A_5}{A_1+4A_2+2A_3+4A_4+A_5}\,\frac{l}{4}$$

When the volume of a mass of earthwork is required its center of gravity may also be found, by this formula, without much extra labor.

ON THE HARDENING, TEMPERING AND ANNEALING OF STEEL.*

From "Iron."

It does not appear that any attempt had been made in this or in any other country to discover the theories of the constitution or properties of steel, till Karsten in 1827 investigated the conditions of carbon in iron, and Jullien in 1852 deposited at the Academy of Sciences, Paris, a paper termed "L'Explication de la Trempe." From that period a good deal has been written chiefly by French metallurgists.

I.—NATURE AND COMPOSITION OF STEEL AND CAST IRON.

Karsten in 1827 says that carbon is contained in iron in three different ways:—(1) As free carbon or graphite. (2) Combined with the whole mass of iron. (3) In the state of polycarburet, dissolved in the mass. In 1852 Jullien advocated, if he did not originate, the theory that iron and carbon do not combine (as true chemical combinations), but that the compounds formed by the two substances are what he terms "solutions," or, as we should translate it into English, only mechanical mixtures. Following Karsten, Berzelius, and others, he holds that amalgams and alloys are definite combinations dissolved in excess of one of the components. He defines "combination" to be a union of elements in definite proportions, the resulting body being different from either component and from any of their other definite combinations. "Solutions," or mechanical mixtures, on the other hand, may occur in any proportions, and the resulting mixture participates in the properties of each component in proportion to its quantity. Your committee find it difficult to acquiesce in the latter portion of this statement. For example, the addition of increasing proportions of tin to copper results in producing harder compounds, instead of softer. Under certain circumstances the addition of a small proportion of tin to cast iron greatly increases its hardness. Barba adopts Jullien's view, and defines steel to be a solidified solution of carbon in pure iron: (Les aciers sont des dissolutions solidifiées de carbone dans du fer chimiquement pure.) Osborne seems to think that carbon exists both in a combined form and uncombined, disseminated in the latter case as graphite; but he does not define clearly what he means by the word "combined." Caron considers the union of the two substances to be a mixture. Gruner takes the same view. Akerman adopts the view that carbon occurs both in combination and as graphite; and also the view of Rinman, that combined carbon may be partly intimately combined, when it may be called "hardening carbon," and partly incompletely combined, when it may be called "cement carbon." He does not define what he means by combination, whether in definite proportions or not. Your committee have not found any modern author holding the opinion that the various combinations of iron with carbon, and with other substances found in steel and cast iron, are definite chemical unions with excess of either one or other of the component bodies. The elaborate evidence adduced by Jullien, which does not appear to have been combated, makes it highly probable that steel and cast iron are only mechanical mixtures of carbon and some other substances in pure iron.

II.—QUANTITY OF CARBON IN STEEL AND CAST IRON, AND ITS STATE.

Barba considers that the solution of carbon in molten iron follows the ordinary laws of solution, that is:—(1) The quantity of carbon which iron can contain in solution increases with the temperature. (2) By slow cooling a part of the carbon separates from solution and is brought into a state of mixture. (3) With rapid cooling, or sufficient exterior pressure, the greater part of the carbon remains in "solution;" rapid cooling acting by the pressure it produces; and, if the carbon is merely mixed, exterior pressure producing solution more or less complete according to the intensity of

* Report to Research Committee of the Institution of Mechanical Engineers.

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the pressure. (4) The temperature at which steel solidifies decreases as the quantity of carbon it contains augments. He remarks that experimental demonstration is wanting to show that pressure is favorable to preserving "solution" when cooling. Osborne says that rapid solidification favors the retention of carbon in the combined state, and by that means it is possible to change grey cast-iron into white. Jullien states (1852) that the properties which the solutions of carbon in iron exhibit are due exclusively to the rate at which the hot solutions are cooled. Following Karsten, he says that the liquid solutions of carbon in iron are homogeneous, because rapidly cooled solid "solutions" are found to be so. He considers that:—(1) Melted cast-iron is a solution of liquid carbon in liquid iron. (2) Grey and soft cast-iron is a solution cooled slowly, and converted into a mixture of mild steel and amorphous carbon or graphite. (3) Grey cast-iron heated cherry-red and plunged into cold water is a mixture of hardened steel and graphite. (4) White cast-iron is a solution cooled rapidly, and consists of a mixture of crystallized carbon in amorphous iron. (5) White cast iron reheated, and while protected from the atmosphere, becomes grey and soft, is grey and soft cast-iron. (6) White cast-iron heated in contact with air, and grey or white iron reheated in closed vessels in a cement of metallic oxide, become mild steel. (7) Steel heated cherry-red is a mixture of liquid carbon in solid iron. (8) Mild steel is a mixture of amorphous carbon in iron, either amorphous or crystallized. (9) Hardened steel is a mixture of crystallized carbon in amorphous iron. He further states that iron absorbs carbon at temperatures ranging from cherry-red to welding heat, and up to a quantity equal to 5.25 per cent. of the mixture; that the properties of steel approach those of iron in inverse proportion to the quantity of carbon; and that the presence of carbon not only increases the fusibility of the alloy but communicates to it, in certain ceses, properties belonging exclusively to crystallyzed carbon or diamond. He also states the temperature of fusion of grey cast iron is higher in proportion as the quantity of graphite is greater, while the temperature of solidification is lower in proportion as the quantity of dissolved carbon in the fluid mass is greater. The lower, therefore, the temperature of solidification of grey cast iron, the higher is its point of fusion; it is only steel that has the same temperature of fusion and solidification. This property of cast iron is common to many bodies, such as bismuth, tin, sulphur and water, under favorable conditions of cooling. Caron states that steel, if hardened by being heated to redness and cooled rapidly, and then dissolved in strong hydrochloric acid, leaves no residue; that the same steel, if raised rapidly to a red heat, and allowed to cool slowly, will, if dissolved as before, leave a residue of carbon, which dissolves on being heated; and that the same hardened steel, if annealed by being kept at a red heat for a long time, and allowed to cool slowly, dissolves more easily, but leaves a residue of carbon insoluble even in hot acid. The conclusion he draws are, that in the first case the iron and carbon are intimately united and dissolve together; in the second case the union is not so intimate, therefore the more soluble body dissolves first, and the carbon, which is not quite modified, yields last; and in the third case the carbon is free, and shows it by its property of resisting acids. What Caron terms a solution of iron or carbon in hydrochloric acid appears to your committee to be probably a "double decomposition." Carbon is very unchangeable, resists the action of acids and alkalies, and bears the most intense heat in close vessels without fusing or undergoing any perceptible change. Baumhauer confirms these statements with respect to diamond, and relates the experiments by which they are proved. He also states that a diamond, when heated for a long time to whiteness in carbonic acid gas, showed prismatic colors on some of its facets. Akerman states that graphite is only mechanically incorporated in pig iron, and can be separated by dissolving the iron in acid. The combined carbon, on the other hand, when the iron is dissolved in boiling hydrochloric acid, escapes as carburetted hydrogen, provided proper attention is given to the dissolving process, so that the boiling commences almost immediately after the addition of the iron to the acid, and is continued uninterrupt-

edly for a sufficient length of time without access of air. When dissolved in cold acids, and warmed a little time after, a part of the combined carbon remains as a black residue, especially if air has ready access. He also quotes Caron's and Rinman's statements with respect to the solution of steel in acid. Gruner states that each temperature corresponds to a maximun of solubility, and that this solubility rises and falls both in the fluid and solid states. Whenever a carburetted iron (steel or cast iron) cools slowly, an intimate mixture of iron and particles of graphite is produced, as in the case of untempered steel and grey cast iron. When carburetted irons are cooled quickly, the separation of carbon is rendered impossible for want of time, and carbon remains dissolved in the iron at ordinary temperatures; saturation then results. The mixture then becomes hardened steel when the proportion of carbon is below 1.5 per cent., and white cast iron when above that quantity.

III.—SUBSTANCES OTHER THAN CARBON ENTERING INTO THE COMPOSITION OF STEEL.

Dr. Siemens is of opinion that high-class steel should contain only iron and carbon: the hardness, temper, ductility, elasticity, toughness and strength depending upon the relative proportion of these elements. But as it is almost impossible to produce such pure metal, other substances, which must, however, be considered as impurities, have to be admitted: these impurities have a certain influence in rendering steel hard, or rather in making it brittle; thus, if phosphorus is allowed, a certain dose of manganese has to be added to prevent cold-shortness, and a smaller quantity of carbon must be used. Manganese is a treacherous element in steel, as its distribution is not uniform, and thus a homogeneous compound is not produced. According to Fernie, a sample of Krupp steel contained 1.18 per cent. of carbon and a trace of manganese, and a sample of American steel 0.23 per cent. of carbon and no manganese; the latter constituted soft metal fit for fire boxes. Fremy (1864) advanced the theory that nitrogen was an essential component of steel; that steel was, in fact, a nitro-carburet of iron. Caron, however, considers it proved that all kinds of iron contain feeble quantities of nitrogen, 0.00011 per cent. and considers that it must be looked upon as an impurity just like silicon, sulphur, and phosphorus. According to F. C. G. Müller, it has been proved that hydrogen, nitrogen, and carbonic oxide are to be found in the pores of Bessemer and Siemens-Martin steel. Cyanogen, tungsten, chromium, platinum, silver and other substances, have been mixed with steel with a view to give it certain high qualities; but Chernoff, Dr. Siemens, and many others are of the opinion that true steel is a mixture or combination of carbon and pure iron alone, and that all other substances are impurities necessarily injurous in pure steel, though sometimes apparently beneficial if they exclude or neutralize more injurious substances. Boman states that Bessemer steel No. 1 (which is necessarily impure), containing only 2 per cent. of carbon, is hardly malleable; while Anosoff found that the hardest "boulat" (the sabre steel of the Tartars), which is perfectly pure, retained its malleability though it contaned 3 per cent. of carbon.

IV.—HARDENING OF STEEL.

Jullien holds that carbon in contact with iron at cherry-red heat becomes liquid, and is absorbed like water in a sponge, like oxygen in liquid silver, or like gas in porous bodies; cooled slowly, the carbon becomes amorphous, and the steel becomes soft as iron; cooled quickly, the carbon crystallizes to depths proportioned to the energy of cooling, and steel becomes diamond set in iron. In your Committee's opinion, this theory, even if it accounts for the hardening of steel, does not account for tempering. What takes place when hardened steel is heated and passes through all the gradations of hardness indicated by their characteristic colors! Jullien quotes Berzelius as stating that when a saline solution, saturated or not, is allowed to cool quickly almost to the congealing point, the periphery which is first cooled becomes less saline than the center; until at last, when the entire mass has solidified, the dissolved salt is found concentrated in the center. From this fact he infers that two bodies dissolving each other, and preserving their independence in solution, must produce solid compounds of varying properties ac-

cording to the rate at which cooling takes place. Furthermore all solid bodies are susceptible of two different molecular structures, dependent on the rate of cooling from the fluid state; but this rate of cooling does not produce the same results on all. Thus gold, silver, and copper, if cast in chills, yield a fibrous structure, while, if cast in sand moulds, they exhibit a crystalline fracture; and the fibrous structure can be changed into the crystalline by a temperature short of fusion. Carbon and glass behave quite otherwise. Diamond, exposed sufficiently long to a high temperature in a covered crucible, becomes amorphous or graphite: hence it may be concluded that, if it could be taken liquid and subjected to energetic cooling, it would crystallize; while under slow cooling it would become graphite. Glass, taken liquid and submitted to energetic cooling, crystallizes; but when annealed, it becomes amorphous or ceramised. Rupert's drops, which are transparent crystallized glass, become opaque if heated for a long time. He therefore considers that a mixture of iron and carbon, if cooled quickly, becomes hard because the carbon crystallizes into diamond; while, if it is cooled slowly, the carbon remains amorphous and comparatively soft. Chilled grey cast iron has a mottled band between the chilled and unchilled parts; this is the zone where the carbon is partly crystalline and partly amorphous. Gruner considers that carbon is dissolved in hot iron: that when cooled slowly the carbon has time to separate as graphite, but when cooled quickly there is no time for separation; and white chilled iron instead of grey cast iron is the result. Soft and hard steel show a similar difference though to a less degree. Barba and Akerman consider that the compression resulting from rapid cooling is the cause of a greater amount of carbon being retained in solution, and prevented from separating as graphite. Your committee find it difficult to accept this theory, because the compression of the internal portion of a piece of steel is caused by the contraction of the outer layers; and these, therefore, must be stretched, as indeed it is well known that they are. But in hardened steel the outer layers, which were most energetically cooled, are the hardest, although they must have been, and probably are, in a state of tension. Akerman, however, considers that compression, or forcing together of the particles, the amount of which is dependent on the rapidity of cooling, produces hardening; and that the intensity of this hardeneng depends on the compactness of the material and its limit of elasticity. By the way of proof he states that cold-working, rolling, and wire-drawing produce similar results.

V.—THE MOLECULAR CHANGES THAT OCCUR IN HARDENING, TEMPERING AND ANNEALING.

The theory announced by Chernoff in 1868 to the Imperial Russian Technical Society appears to explain in a satisfactory manner the molecular changes that take place in steel when subjected to changes of temperature. His view is that:—(1) There is a certain temperature, *a*, such that steel of whatever quality will not harden if heated to any temperature below *a*, and energetically cooled. (2) There is some higher temperature, *b*, above which steel changes from the crystalline to the amorphous condition. (3) If heated to a temperature between *a* and *b*, steel may harden, but does not change its structure, whether cooled quickly or slowly. (4) If heated above the temperature *b*, and up to the melting point, steel has a wax-like structure, is incompressible, and tends to crystallize into larger crystals if left to cool slowly undisturbed, but into smaller crystals if hammered or if rapidly cooled. Fine grain is essential to good, tough steel; hence, by heating up to the temperature *b*, so as to produce the amorphous condition, and then cooling suddenly to below *a* in oil or water, good steel can be obtained. The temperatures *a* and *b* vary with the nature of the steel. Chernoff illustrates his views by reference to the behavior of alum undergoing crystallization; and the close reasoning of his remarkable paper carries a strong conviction of the correctness of the views he advocates. There are abundant illustrations of his theory to be found in the many writers on steel who have been consulted. Thus Hackney states that quenching mild steel improves its tenacity and ductility. Riley expressed an opinion that it was not so much the percentage of carbon as the way in which the rails had been cooled that should

be taken into consideration, when two rails of the same chemical composition differed in hardness. Barba states that annealing should not be done at too high a temperature, otherwise the steel will crystallize with slow cooling, will lose elasticity, and become what is ordinarily called "burned." Caron states that "burned" iron can be restored by raising it to a white heat, and then placing it under the rapid action of a steam hammer. Chernoff also describes and explains the case of a "burned" ingot of steel, which he treated in the above manner and restored to its proper condition. Osborne states that steel has a remarkable property of remaining in a pasty condition through a considerable range of temperature below its melting point; and that bar-iron acquires a largely crystalline structure when exposed for a long time to heat considerably below fusion.

Professor Gore, in 1869, and subsequently Professor Barrett, in 1873, drew attention to certain anomalies that occurred in the expansion and contraction of iron wire: and in 1877 Professor Norris published the results of his experiments on the same subject, which appear to confirm Chernoff's theory in a remarkable manner. In cooling a strained iron wire from redness, it was found that the contraction due to cooling was, at a certain point and for a limited period, changed into an action of elongation. In good iron wire this irregularity could not be detected, but in hard wire and steel it was very apparent. The wire has to be raised to a very high temperature before the temporary elongation during cooling can be seen; and it does not take place if the wire is heated only just beyond the temperature at which it occurs. Professor Norris' researches have led him to the following conclusions:—(1) That in steel, and in iron containing free carbon, there is a contraction or shortening which is excited by heat, and which proceeds simultaneously with the dynamical expansion and masks its true amount. This is divisible into high and low temperature contraction. (2) That similarly there is a cooling expansion or crystallization, which comes in during the dynamical contraction and masks its true amount. (3) That these effects, due to crystallization and decrystallization, are the causes of the so-called "kicks," or temporary contractions and expansions, which occur during the heating and cooling respectively of the steel. (4) That the low-temperature contraction and cooling expansion are due to decrystallization and crystallization, which occur during the acts of heating and cooling; while the "kicks" themselves are simply the thermal effects associated with these changes, and are proportionate to their extent. (5) That protracted annealing, *i. e.*, extremely slow cooling, brings about molecular separation of the carbon and iron. Steel in such a state contracts greatly when high temperatures are reached, producing the effects of contraction which are seen at the ends of the heating, and which are due to the condensation produced by the recombination of the carbon and iron. Steel in this state is less susceptible to cooling-expansion (or crystallization), and therefore to low-temperature contraction on subsequent heating." It would seem that the "kicks" observed by Professor Norris probably occur somewhere in the region of Chernoff's temperatures *a* and *b*, where a change in the molecular structure of steel appears to take place according to his theory. At any rate it is plain that molecular changes of some kind do occur, and manifest themselves by altering the bulk of the metal.

It has already been stated that Müller has demonstrated the presence of hydrogen, nitrogen and carbonic oxide in the pores of Bessemer and Siemens-Martin steel. Edison, at the recent meeting of the American Association for the Advancement of Science at Saratoga, has extended the observations at Döbereiner, St. Clair-Deville, Troost, Faraday and Graham; and has not only applied the facts ascertained to explain the destruction of refractory metals, such as platinum and iridium, under long-continued high temperatures, but has discovered the means of overcoming those defects, which have proved a serious hindrance to the extension of electric lighting. Edison noticed that the effect of incandescence on wires was to produce, all over their surface, innumerable fine cracks. When the incandescence was maintained for twenty minutes these fissures became so enlarged as to be visible to the naked eye; and, when still further continued

for several hours, the cracks united and the wires fell to pieces. A number of experiments have led him to the conclusion that the cracking of the surface of the metal is due entirely to the occluded gases, imprisoned within its pores, which become expanded and are driven out under the action of heat. By heating spirals of platinum wire gradually, by means of a transmitted electric current of periodically increasing strength, and within an exhausted chamber, the gaseous substances contained within the metal were gradually withdrawn; and by allowing the metal, in the interval between each increase of temperature, to cool down *in vacuo*, a series of expirations from the surface took place, alternating with a closing up and welding together again of the minute fissures through which the gentle heating *in vacuo* had enabled the gases to escape. By continuing this simple operation it has been found possible to change completely the physical character of metals; increasing their hardness and density to an extraordinary degree, and raising their points of fusion so high that they are perfectly unaffected at temperatures at which most substances would be melted and even volatilized. A spiral or ordinary platinum at a white heat softens and loses its elastic and rigid character; but platinum, after having been treated in the manner above described, becomes as rigid as steel, and as homogeneous as glass; and retains these properties when glowing under the most intense incandescence. The metal so transformed cannot be annealed by any known process.

It appears to the committee that the expulsion of the gases contained in the body of the metals may have the effect of bringing the ultimate atoms closer together, increasing thereby the force of their cohesion, and consequently resisting more strongly any re-arrangement that would be necessary in annealing. It would appear also that the existence of gases in the pores of metals is an attribute of their normal states; and that the expulsion of the gases increases hardness and necessarily raises the melting point on account of the stronger cohesion of the atoms. May it not be that the sudden contraction in hardening steel has the effect of expelling occluded gases; that subsequent tempering, by raising the temperature, has the effect of permitting a fresh absorption; and that the iridescent colors which accompany tempering are due to the change of surface caused by the infiltration of gases? Another view is that the mere heating of steel to the proper temperature for hardening is sufficient to expel a portion of the gases, which are kept out by sudden cooling, and are slowly re-absorbed in tempering. Graham states that platinum at a low red heat will absorb four times its volume of hydrogen, and that palladium condenses more than 600 times its volume of hydrogen at a temperature below that of boiling water. May not steel therefore possess analogous properties with respect to some of the gases constituting the air? May it not absorb these more freely as the temperature of tempering rises, and so gradually becomes restored to its original softness?

VI.—Directions in which further Investigations appear to be needed.

(1) To investigate whether Edison's theory can be applied to the explanation of the hardening and tempering of steel? and to ascertain by experiment whether absorption and expulsion of gases take place. (2) To determine by analysis whether any chemical difference exists between the outer and inner layers of a piece of hardened steel, which before hardening was of homogeneous structure. (3) To ascertain whether there is any connection between Chernoff's theory and Norris' observations on the contraction and expansion of wires.

Novel Gunnery Trial.—Major-General C. W. Younghusband, C. B., Royal Artillery Superintendent of the Royal Gun Factories, Royal Arsenal, Woolwich, has gone to Italy to witness a gunnery trial of a novel and interesting description, the gun being one of 100 tons weight, but made of cast iron instead of the wrought iron or steel, which mod ern artillerists regard as indispensable for heavy weapons if they are to fire large charges. The strain to which this cast iron piece of ordnance will be subjected is not stated, but the gun is described as strengthened with hoops of steel, and theoretically capable of great endurance.

ENGINEERING PROGRESS DURING THE LAST FIFTY YEARS.

Address of WILLIAM HENRY BARLOW, Esq., F. R. S. President of The Institution of Civil Engineers.

THE important rank which The Institution of Civil Engineers has acquired in this country, and the estimation in which it is held by foreign countries, while they are circumstances of which we must all feel proud, necessarily impose upon its members, and especially on those who take a leading part in its affairs, duties of corresponding responsibility.

And in taking the high position of President to which you have elected me, and for which I thank you as being the highest honor my professional brethren can bestow, I feel it to be accompanied by duties of so onerous a character, that I should have hesitated to undertake them, did I not feel that I may rely with confidence on your aid, not only to maintain, but if possible to raise yet more, the high standing which this Institution has already attained.

It becomes my duty this evening to offer to you some observations in the nature of an address, but the variety of subjects which have been so ably treated by my predecessors in office, render this task one of considerable difficulty, and I must claim your indulgence while I endeavor to fulfill it.

Having commenced my professional career in the same year as that in which this Institution received its Royal Charter, namely 1828, I propose to draw your attention to one or two of the great features of change and progress in engineering which have arisen since that time; because these changes have had a marked and important effect on the conditions under which we live in the present day, as compared with what they were fifty years ago. It is in fact difficult for those who lived at that time to recall all the circumstances of their then daily life, so much have we become habituated to the facilities with which we are now surrounded; and I think it is not claiming too much to say, that some of the most important of those facilities are the direct result of applications of engineering science.

There is one circumstance of my early life which left a strong impression on my mind, and which I may be pardoned for mentioning, namely, the first time I was present at a meeting of this Institution. This was in 1827. I went accompanied by my brother, Mr. P. W. Barlow, who was then an associate, and is now one of our oldest members. There were several men then present whose names are well known to us, among them Mr. Joshua Field, Mr. James Simpson, Mr., now Sir, John Macneill, and Mr. Henry Palmer; but the one who riveted my attention was the great Thomas Telford, who occupied the chair, and who to me seemed as a superior being gifted with higher attributes than ordinary men. It appears by the records of the Institution that the whole number of persons present at that meeting including visitors, was twenty three—and that was considered a well-attended meeting.

Of the large features of change which have appeared since this Institution received its Charter, there are none which have produced so marked an influence on the well-being of this country, and on the world at large, as the improvements in the means of communication, by the application of steam to locomotion on land and in ocean navigation. And as allied to this subject the communication of intelligence by the utilization of some of the powers of electricity.

It is not alone in the economical results, or in the impulse and larger area given to commercial enterprise, that advantage arises, but mutual interests become established between the inhabitants of different countries; people are induced to travel and enlarge their sphere of observation; dwellers in distant places are brought together, and the opportunities for interchange of ideas and thought are increased.

For some time previous to 1828 great urgency had been manifested to improve the means of transport of goods and minerals. The canals, which in this country date from about the year 1758, and estimated in 1836 to exceed 3,000 miles in length, were found inadequate to the wants of the commercial interests at the time in question.

Much attention was bestowed on turn-

pike roads, some of the main lines of road communication having been brought to a high degree of perfection under the direction of Telford.

Tramways, which date long before canals, existed in considerable numbers in the mineral producing districts; but they were for the most part of cast iron, and belonged to private owners, few of them being applied to the general purposes of commerce.

There were also some railways, distinguished from tramways, as their name implies, by being formed of rails instead of tram-plates, among which was the well-known Stockton and Darlington Railway.

The application of steam in locomotive engines was in an early experimental stage.

It is needless to mention the name of George Stephenson, and the important part he took in the early establishment of railways. His name will always be associated with railways, not so much on account of the engineering ability he displayed, but because it was due to his strong convictions and his force of character, that the Liverpool and Manchester Railway Company adopted locomotive engines for their tractive power; and the commercial success of this enterprise formed the starting point of that great railway system which now spreads its network and ramifications in many parts of the world.

That the discovery of a better system of locomotion by land was greatly needed, is evinced by the rapidity with which the railway system has spread, and the extent to which it has already been carried.

The Liverpool and Manchester Railway was opened in 1830, and within forty-five years of that time Sir John Hawkshaw, in his address to the British Association, estimated the total length of railways then existing at 160,000 miles, and the capital invested in their construction £3,200 millions.

Since that time (1875) there has been a further considerable extension, and the growth of the railway system continues. And when it is considered that China has at present no railways, and Japan is only beginning, that the whole of Africa, whose population is estimated by Mr. Brassey at between 350 and 400 millions, is almost without railways, as well as a large part of South America and Central Asia, and that many of our colonies are ill provided, it becomes obvious that the railway system must continue to increase as time goes on.

In the United States of America the construction of new lines is actively proceeding, and even in this country, which seems well supplied in proportion to its area and population, the increase proceeds, not so rapidly as it has done, but still it continues.

In the years

		Miles.		£.
1846	the length was	2,765,	the traffic	7,565,569
1854	" " "	8,053,	" "	20,215,724
1862	" " "	11,551,	" "	29,128,558
1870	" " "	15,537,	" "	45,078,143
1878	" " "	17,333,	" "	62,862,674

The traffic receipts exhibit two separate elements of increase, one being due to the increased length of line, and the other to the continuous growth of traffic on lines already opened—a growth which is found to continue even on the oldest lines.

It is not easy to separate these two elements in the traffic returns, but having devoted some pains to the inquiry, it appears that traffic growth, as an average throughout all the lines in the United Kingdom, and taken over the whole period of thirty-two years, is rather more than £100 per mile per annum.

The traffic for the three years ending in 1878 has been almost stationary, but it was preceded by such very large receipts between 1870 and 1874 that at the date of the last annual returns, it was hardly back to its normal condition.

To meet the exigencies of this growth of traffic a total reconstruction of the permanent way, engines, and carriages, has been necessary, as well as extensive additions to stations. The rails first laid down were of wrought iron, 35 lbs. per yard. Those now used on the main lines are of steel, between 80 and 90 lbs. per yard, and on a large part of the principal railways four lines are laid, enabling the fast trains to be separated from those of slower speed, thus increasing very largely the carrying capacity. The engines, originally limited to five tons in weight, and burning coke for fuel, are replaced with others of greatly improved construction, weighing, with their tenders, from fifty to seventy-five

tons, and burning the cheaper fuel of coal.

Carriages first made after the pattern of coach-bodies, with three small compartments on four wheels, are now replaced by large commodious vehicles running in two six-wheeled bogie frames, and the Pullman carriage from America, with its drawing-room car and sleeping compartments, has been successfully introduced.

While these improvements have added much to the comfort of railway traveling, a complete system of block-signaling, the employment of continuous brakes, and the interlocking of points and signals, have greatly increased the safety, notwithstanding the higher rate of speed attained and the largely increased number of trains.

It is impossible to speak of railway traveling at this time, without the mind recurring to the late most lamentable accident at the Tay Bridge.

This grave disaster is now the subject of a searching investigation, the results of which will necessarily be looked for with great anxiety.

Should this inquiry reveal, as we may hope it will, the probable cause or causes which have led to these distressing results, it will afford information of the greatest value for future guidance.

Excepting this one unprecedented accident, railway traveling exhibits highly satisfactory results as regards the safety of that mode of traveling—whether considered in reference to the enormous numbers who travel, or the distances accomplished by habitual travelers.

The distance traveled by some of the company's servants is remarkable. Mr. Allport states that some of the older guards of the Midland have traveled 2,000,000 miles, and Mr. Besley mentions two guards on the Great Western, one of whom is estimated to have traveled 2,400,000 miles, and the other 2,500,000 miles, a distance which may be otherwise expressed as more than ten times that of the moon from the earth.

Street tramways, which have long been used in America, are now introduced to a considerable axtent in the principal cities and towns of Europe. They are evidently a great convenience to a large class of the public, but whether from the mode of their construction or from insufficient care in the maintenance of the roads, some of them render the traveling of other carriages along the same lines of roads very unpleasant—a defect which it is hoped may be remedied. Efforts are now being made to introduce tractive force upon them other than horse traction. Among these are a modified form of the locomotive steam engine, the compressed-air engine, and an ingenious arrangement called the fireless engine.

Steam navigation had made some progress in 1828. The number of steam vessels then existing being 344, with an aggregate tonnage of 30,912 tons, showing an average of about 90 tons each. They were chiefly employed in river and coasting traffic.

In the United States of America further progress had been made, the magnificent rivers of that country being among the earliest means developed for internal communication.

At that time all our ships, including war ships, were of timber. With a few exceptions steam had not been introduced into the navy, and it was considered derogatory in the service at that time to be appointed to the command of a steam vessel.

Ocean steam navigation, which now forms the links of communication between distant countries, had not been attempted, and it constitutes another of those geeat achievements due to the application of steam to locomotion.

As the Liverpool and Manchester Railway was the starting point of the railway system, so were the almost simultaneous voyages of the "Sirius" and the "Great Western" in 1838 the starting point of ocean steam navigation. Its commercial success and the extent to which it has been carried are due to improvements which involve a greater range of scientific knowledge than railways, and are the result of deep thought and unremitting perseverance of many of our ablest men.

We are indebted here to the improved knowledge of the forms and lines of ships—a subject so ably treated by our late lamented colleague, Mr. Froude—to the substitution of iron and steel for timber in the construction, whereby ships are made of greater length and strength and carrying capacity, to the greater advantages in propulsion obtained by the screw propeller, and to the

improvements in the steam engine, whereby the consumption of fuel has been so largely reduced.

The capital invested in ocean steamships, though large, is not of that magnitude required for railways, but it is rapidly increasing, both as regards the number of ships employed and the dimensions and power given to them.

It appears that prior to 1836 the largest ships afloat were between 800 and 900 tons burthen, and about 220 HP. With the exception of the "Great Eastern," which, though grand in its conception, was in advance of the wants of the day, there has been an almost continuous growth in the dimensions and power employed; and there is now in course of construction, and nearly completed, the steamship "Servia," belonging to the Cunard Company, 7,500 tons burthen, 10,000 HP., 500 feet in length, built entirely of Siemens-Martin steel, and calculated for a speed of 17½ knots per hour. The Allan Company is building another great ship of 5,500 tons burthen, also to be entirely of steel. These magnificent ships will, however, be surpassed in magnitude by the war ships now building. The "Inflexible," for the English navy, will be 11,600 tons burthen, 8,000 HP., and carry four 80-ton guns; and the "Italia," for the Italian navy, will be 13,200 tons burthen, 18,000 HP., and carry four 100-ton guns.

The great ocean steamships, combining sailing and steam propulsion, present in their structure, and the various requirements necessary for the speed, regularity and safety with which they are worked, a number of mechanical and scientific applications of high order, every one of which is the result of much study and mental labor. But the ponderous armor-plated turret ships, armed with their powerful artillery, containing steam engines for propulsion, others for turning the turrets, steering, lifting anchors, working hydraulic machinery for moving the guns, and numerous applications of electricity for signaling and firing and electric lighting, constitute as a whole a most surprising combination of science and skill.

In these ships the improvements are of two kinds, one being directed to the ship itself, its structure and its propulsion, the other to performing different functions of manipulation; and as regards these latter, admitting the excellence of each of the individual contrivances, yet there is a point at which their advantage may be overbalanced by their number and complexity.

The extension of navigation has necessitated great increase in docks and harbor works. These works, some of them of great magnitude and cost, are too numerous to describe in detail. They constitute as pecial branch of engineering of a very important character.

Very large extensions of docks have been made in London, Liverpool, Southampton and Hull. New docks have been constructed at Avonmouth and Portishead in connection with Bristol, besides many other like works in different localities.

Among the principal harbor works are those of Portland, Holyhead and Dublin. The progress in harbors, however, does not appear to have proceeded so rapidly as to meet the full requirements of the time.

The number of wrecks annually reported points to the necessity of more harbors of refuge, and there are evidences that the due development of steam navigation in some parts of our coast is impeded by insufficiency of harbors.

This is especially observable in regard to the communication between England and France. The Channel passage, from its extreme discomfort, interferes prejudicially with the proper interchange of traffic between these countries, and has led to many suggestions for its amendment.

It is satisfactory to learn that the French Government is about to improve the harbors on their coast—a movement which we must hope will be followed by a corresponding action on the part of this country.

The steamboat called the "Calais-Douvre" is a praiseworthy and to a certain extent successful attempt to make the best of the existing harbors, and mitigate some of the inconveniences of this short sea passage; but this vessel only runs on summer service, and the greater room and superior accommodation afforded by her is not attainable in the rough winter months.

Canals have ceased to extend in England, to any appreciable degree, since

the establishment of the railway system; but they progress in many parts of Europe, where, in conjunction with river navigation, they afford great facilities for trade carried on in small vessels.

The most remarkable work of inland navigation of our time, one which has exercised a great influence on the ocean navigation of the East, is the Suez ship canal—a work which will always render famous the name of its author, M. De Lesseps.

Another work of great influence on the inland navigation trade of Eastern Europe is the deepening of the mouths of the Danube, by Sir Charles Hartley.

There are also two important American works, not yet entirely completed, one being the deepening of the channel between Long Island and the mainland, rendered specially interesting by the extensive blasting operations at Hell Gate; the other is the improvement and deep ening of the south channel of the Mississippi, by Mr. Eads. In this work, by the application of comparatively inexpensive means, the channel has been deepened so as to permit the passage of much larger ships to New Orleans.

The communication of public and private intelligence was formerly dependent on the speed at which a man could travel, and, excepting a limited application of the old semaphores, the Government were in like manner restricted in their intelligence department.

The introduction of electricity for the purposes of telegraphy, and more recently for the production of light, and lastly for the transmission of power, is a matter of especial interest, as being one in which the labors of the philosopher, and the discoveries originating in his laboratory, are made directly applicable to the uses and conveniences of man.

As in many other discoveries and new applications of science, the form which the telegraph received to bring it into actual use was preceded by suggestions, showing the conception of the idea. Sir Francis Ronald, as is well known, made a telegraph worked by frictional electricity, of which he published an account in 1823.

A much nearer approach to the needle telegraph was made in an experiment by my late father (Professor Barlow), who used a galvanic battery, and deflected small compass needles placed in different parts along the conducting wire. By this experiment, of which an account appears in the "Edinburgh Philosophical Journal, of 1825," he found that considerable loss of power arose with increase of length, and he was in consequence discouraged from proceeding further than determining some of the laws on which that decrease depended, and also the relative conductivities of different sizes of brass or copper wire. I was present at this experiment, and though only a lad at the time, I well remember that the battery used was the large quantity battery he employed in his experiments on electromagnetism, that no coil was used, and that the wires were hung to the posts without any insulation.

The form which the telegraph received at the hands of Sir Charles Wheatstone and Sir William Cooke, and its application to signaling on the Blackwall railway in 1838, established its practicability. Through the influence of Mr. Robert Stephenson and Mr. Bidder, a company was formed to work this invention for commercial purposes, and from that time, by the aid of numerous inventions and adaptations, and especially by having overcome the difficulty of crossing the ocean, the system has spread with a rapidity to which there is no parallel.

In 1875, the total lengths of wire in operation was estimated at 400,000 miles. Since that time the Eastern Telegraph Company has extended its lines to the Cape of Good Hope, two new cable lines have been laid by Dr. Siemens between France and America, and large extensions and duplications of land lines have been made.

There are no means of tracing the traffic growth of telegraphy, but by the introduction of the duplex system and the automatic working, together with other most ingenious contrivances, the traffic must have extended in a far greater proportion than the length of wire in operation.

Another application of the telegraph now commencing in this country, and already in considerable use in America is the telephone, first publicly exhibited by Professor Bell at the Philadelphia Exhition in 1876. The power of transmitting the sound of the human voice and its articulation gives a high scientific inter-

est. Its value as a commercial instrument consists in saving the time required to write, transmit and re-write telegrams.

The diminution of power arising from increase of length in the conducting wire, as pointed out by my father in 1825, renders it necessary to re-transmit telegrams at the end of long cables.

On land lines, or in short cables working in connection with land lines, this difficulty is surmounted by relays of power applied at fixed stations, and by employing this ingenious expedient on the Indo-European telegraph, Calcutta has frequently been put into direct communication with London, a distance of 7,000 miles.

We are indebted to Professor Morse for what may be termed an extremely "happy thought," namely, the system called the "dot and dash." It constitutes a species of articulation, which conveys intelligible meaning by the relative intervals of continuance and discontinuance of action. It is applied in telegraphy, both in writing and in conveying messages by sound as well as by sight; and Sir William Thompson has for some time passed urged its adoption, where it would be of the greatest importance to the safety of navigation, namely, as a means of distinguishing between lighthouses.

I fear that I have occupied your time too long on the subject of improved communication, but, excepting printing and the steam engine itself, no applications of physical science appear to have produced such extensive and important effects.

The penny postage, for which the name of Sir Rowland Hill will always be renowned in the annals of this country, could not have existed without the aid of railways. Neither would it have been possible without their aid, combined with that of telegraphs, to circulate over large areas, newspapers at the cost of one penny, containing telegraphic information of events which happened in distant parts of the world on the day of their publication.

The subjects of artillery and armor plates were ably put before you ten years ago in the address of your past President, Mr. Gregory. Since that time the contest between guns and plates, and the unavoidable competition among nations for superiority of armaments had led to gigantic apparatus for attack and defence. As the magnitude and power of guns have increased, changes have been required in the metal employed in their construction. In 1828 the largest guns and mortars were made of cast iron. In the next stage of advancement wrought iron was used. And now that guns of the weight of 80 tons and 100 tons are constructed, the metal employed is steel, which is universal, at least so far as regards its adoption for the interior lining.

The controversial question as to the employment of steel for the whole gun, instead of a lining of steel with an iron covering, and as to breech loading and muzzle loading, together with many other interesting and important inquiries relating to large guns, are now under investigation by a very carefully selected tribunal, and the results of that inquiry are looked forward to with great interest.

Water supply and drainage form a branch of engineering which, as effecting sanitary conditions, is now receiving much attention. Your late President's address having been mainly directed to water supply, it only remains to add that his project for utilizing Lake Thurlmere for the supply of Manchester received the sanction of Parliament last session. Important works of drainage and other improvements have been effected in most of our principal cities and towns.

By the action of the City of London, and at a later period the Metropolitan Board of Works, the condition of the metropolis has been greatly improved and embellished. Old London, Blackfriars, and Westminster bridges, which in 1828 encumbered and obstructed the navigation of the Thames, have been replaced by others affording a much larger water-way. The sewage, which used to deliver its black streams at intervals along both river fronts, has been carried away by the great drainage works of Sir Joseph Bazalgette, to whom we are also indebted for the Thames embankment works. Under his advice, and that of Colonel Hayward, numerous street improvements have been made, and in the new buildings bordering on them, the hand of our architectural brethren is manifest in the greatly improved appearance of the metropolis.

If Vauxhall bridge be taken as representing the boundary between London and its suburbs in a westerly direction, there have been three suburban bridges built, namely, Chelsea bridge, Albert bridge and Wandsworth.

Eastward of Vauxhall, in what may be considered the active metropolitan area, the only additional public communications made across the Thames during the last fifty years are the Lambeth bridge and the Tower Subway, both constructed by Mr. Peter W. Barlow; and Mr. Brunell's foot-bridge, since removed and replaced by the public foot-way in connection with Charing Cross railway bridge. But the extensive increase of the traffic, and the general growth of the eastern and more commercial part of the metropolis, produce such great and increasing difficulties with the traffic of London bridge, that some other road communication to the eastward of that bridge cannot much longer be delayed.

In the more ordinary operations of building, one of the noticeable changes is in forming foundations by iron cylinders or caissons instead of the coffer-dams formerly used. This newer mode of construction was early employed in railway bridges by Sir William Cubitt and Sir Charles Fox and its most extended and most recent example is found in the great bridge across the Tay.

The use of concrete has largely increased with the improved knowledge of cements. Concrete was formerly used chiefly in foundations and backing of walls; but in the large extension of the Victoria Docks by Mr. Meadows Rendel, it has been employed for the entire walls, including their face-work and coping. About 450,000 yards have been used in these works with very successful results.

The employment of hydraulic machines has largely increased, some being used for producing great pressures and moving great weights, others are made of quicker movement, water motors, applicable to cranes, hoisting apparatus, opening lock gates, and many other purposes.

One of the most striking applications of the hydraulic press is that employed by Sir Joseph Whitworth in the compression of molten steel. Those who have witnessed this process will be aware of the enormous difficulties which had to be overcome in subjecting large ingots of molten steel to a pressure amounting to 6 or 7 tons per inch. The pressure thus obtained is kept up continuously for an hour or more, and completely closes up every air space, gas space or other interstice, and thus renders the ingot perfectly solid and sound in all its parts.

By a further application of the hydraulic press at these works, the use of the hammer is dispensed with in large forgings of steel; the red-hot metal is pressed into its required form by arrangements under easy guidance and control. Forging by hydraulic pressure has at least the appearance of being a far superior process to the rough and noisy hammering which accompanies ordinary forging. It is practised in Prussia, as well as in this country; several specimens of the work were exhibited at the Philadelphia Exhibition of 1876.

The employment of gas as a means of illumination, which was only beginning in 1828, has increased in a remarkable degree during the last fifty years. The length of gas mains in the metropolis alone was, at the end of last year, 2,500 miles, employed in supplying all the private consumers, and about 58,000 public lamps for street lighting.

Mr. Harry Chubb informs me that in the year 1878 the quantity of coal decarbonized was 1,715,000 tons, and that besides producing nearly 17,500 million cubic feet of gas, there were residual products sold of the value of £745,000.

The coal used appears to be about four-tenths of a ton per annum per head of the population, and of the gross revenue only five per cent. is derived from street lighting, while 20 per cent., or about four times this amount, arises from the sale of residual products. The remainder, or seventy-five per cent., is from gas to private consumers.

The capital invested in metropolitan gas works is about £12,000,000, and for the whole of the United Kingdom £40,000,000.

The brilliant electric light, for which, in its present form, we are indebted to the discoveries of Faraday, has latterly attracted much public attention. Some attempts were made to utilize this light,

when its source was derived from galvanic batteries, in which manner it was first produced by Sir Humphrey Davy; but the more recent electro-dynamic machines have placed lighting by electricity on a totally different footing to that on which it formerly stood.

The exhibitions of this light in this and other principal cities during the last year, and the valuable evidence given in the Report of the Select Committee of last session on Lighting by Electricity, leave no doubt of its applicability to many important purposes. It is, in fact, already established in lighthouses where its intensity and power are of the highest value. In large public buildings, in railway stations, and some large shops, in large open spaces, and for street lighting there are already many examples of its application. Whether it can be divided so cheaply and rendered sufficiently convenient for domestic purposes has yet to be ascertained.

In some of the evidence given before the Select Committee, and in the Report itself, there appears to be some confusion between the intensity of light and its illuminating power. The distinction ought not to be overlooked. The intensity of a light bears the same kind of relation to its illuminating power as the specific gravity of a substance bears to the weight of the substance. Many powerful minds are now directing their attention to electric lighting, and we daily receive evidence of its improvement and advance.

The 20-horse-power-engine put down only last year to work twenty lights in its immediate vicinity on the Thames Embankment, has, by improvements applied since that time, been made to work sixty lights, some of them at a distance of more than a mile and a half measured along the conducting wire.

The latest application of electricity, namely, the transmission of mechanical energy, was suggested by Dr. Siemens, in his address to the Iron and Steel Institute in 1877. The laws which govern the size of conductor, and other features as to its economy as a transmitter, were fully explained at a meeting of this Institution subsequently, and have since received practical confirmation. Sir William Armstrong has availed himself of it for working a circular saw placed at the distance of a mile from the waterfall which supplies the power. The deep-sea sounding line on board the "Faraday" is hoisted by mechanical energy thus transmitted from the engine, and Dr. Verner Siemens has succeeded in obtaining locomotive power sufficient to convey thirty persons by similar means.

It appears that including all sources of loss from converting and reconverting the energy from friction in the machines, and from resistance in the conductor, 50 per cent. of the original power can be realized at a mile distance, and that with adequate provisions against heating, Dr. Siemens' conclusion that it is "no 'dearer' to transmit electromotive power to a greater than to a smaller distance" will be realized.

The application of wrought iron in the superstructure of engineering works commenced with suspension bridges, where the metal is subjected only to tensile action. Its employment in large tubular girders designed to resist rupture by transverse strain, originated with Robert Stephenson, Sir William Fairbairn having carried out the first experiments for him in 1845, and assisted materially with his valuable suggestions.

In the tubular bridge of Conway, and in the subsequent larger work over the Menai Straits, the iron was used in the form of riveted plates, a mode of construction since employed extensively in railway bridges.

Before the completion of these works another step was made in advance by girders of this metal framed together in open work. This description of girder involved problems in determining the amount of stress in each member of the structure, which are specially interesting from the exact manner in which the results can be ascertained, and the several parts proportioned to the work they have to perform. It is to these circumstances, and to the greater proportionate depth which can be given to this class of girder, that its greater economy is attributable.

The improvements effected in the manufacture of steel assume the character of new discoveries, which are tending to revolutionize the whole of our great iron industries.

The Bessemer process, followed by that of Dr. Siemens and Mr. Martin, by producing good steel at a very low rate

of cost, has displaced a great deal of the iron formerly used in this country—a movement likely to be accelerated by the more recent labors of Mr. Bell and Messrs. Thomas and Gillchrist, in the dephosphorization of the Cleveland ores.

Besides the advantages which steel has over iron for rails, wheel-tyres, and other purposes where it is exposed to wear, and for structural purposes on account of its superior strength, there is a general gain to the community in the production of steel instead of iron, arising from the smaller demand made upon our coal resourses for its manufacture.

To make a ton of iron, about six tons of coals are required, but to make a ton of steel only three tons are necessary; and as it is stated that nearly 50,000,000 tons of coal are annually consumed in iron and steel works, the saving in coals by the substitution of steel in place of iron has been truly called a "national gain."

The production of modern steel is a subject which I have followed from its commencement with great interest, being early impressed with the importance of introducing a stronger material than wrought iron into engineering structures.

Acting as a member of a committee of engineers who made an extended series of experiments on steel, the results of which showed conclusively its applicability to structural purposes, being aware also that the consideration of the subject had been frequently urged upon the Government by Sir John Hawkshaw, I took the opportunity of having to make an address to the mechanical section of the British Association at Bradford, to bring the whole subject to their notice. The British Association then appointed a committee to confer with the Board of Trade, by whom after much correspondence the question was referred to Sir John Hawkshaw, Colonel Yolland and myself. This resulted in the adoption of a co-efficient for steel of $6\frac{1}{2}$ tons to the inch, that of iron being 5 tons, it being further understood that for steel of high qualities the co-efficient should be raised by agreement to a suitable amount, due precautions being observed in the testing.

It would be superfluous to point out to members of this Institution that in engineering works requiring large spans, where the weight of the structure is large in proportion to the load to be carried, the economy produced by employing steel instead of iron will be in a much greater ratio than the relative strength of those metals.

Two great bridges are now in course of construction, one being a public road bridge between New York and Brooklyn, designed by Roebling, having one span of 1,595 feet; the other is a railway bridge across the Firth of Forth, designed by Sir Thomas Bouch, which will have two spans, each of 1,600 feet. In both these bridges the employment of steel becomes a necessity, because the weight required to make them in iron would render them impossible.

Although we know enough about steel for ordinary structural purposes, there are properties belonging to that material which greatly need further experimental inquiry. Untempered steel is nearly like good iron in two of its characteristics. Firstly, it possesses nearly the same modulus of elasticity; and secondly, the force required to extend it to the limit of its elasticity, or the force at which an appreciable permanent set first appears, is about half that required to produce rupture.

The superior strength of untempered steel over that of good wrought iron is proportionate to the greater range of its elastic action; and the ratio which this greater range of elastic action bears to that of iron varies with different qualities of steel. But the strength of steel may be greatly increased by tempering in oil, a process now in considerable use. There are no experiments to show whether the increase of strength so obtained is due to a still further increase of the elastic range, or to a change in the modulus of elasticity.

Experiments are also wanting to determine what change, if any, arises in the specific gravity of metal when under strain within its limit of elastic action. This information is essential for the correct computation of the strength of cylinders subjected to internal pressure.

Within certain limits the stretching of iron and steel beyond its original elastic limit increases the strength and the range of elastic action. The process of cold rolling is an example of this effect. In

the Philadelphia Exhibition a large amount of the shafting for driving the machinery was so made. It presents a highly finished appearance, and is known to increase both the tensile and transverse resistance.

Steel wire, drawn cold, exhibits remarkable strength. The pianoforte wire used by Sir William Thompson, in his deep-sea soundings, bore 149 tons to the inch, with an elastic range equal to $\frac{1}{80}$ part of its length, the result in this case showing about the same modulus as iron, and an increase of strength proportionate to the increased elastic range. It is probable, however, that in this, as in some other cases, the increase of strength is accompanied by a great loss of ductility.

The United States Government have recently had constructed a very powerful and accurate testing machine, capable of exerting tensile and compressive strains of 400 tons. This machine has been especially arranged for the investigation of the mechanical properties of steel.

The great advance in practical knowledge has been accompanied with a marked extension of the knowledge of physical sciences; and within the last ten or fifteen years the educational departments of the country have undergone great changes in this respect. By the recent returns issued by the Science and Art Department of the Committee of Council, it appears that the number of schools in which elementary scientific instruction is given, has increased in eleven years from 212 to 1,297. That the number of students who came up for examination has increased during the last seven years from 18,750 to 40,086, and that the numbers of first classes in elementary and the advanced stages has risen in that interval from 2,431 to 11,488.

Mr. Fowler, in his address in 1866, dwelt at some length on the kind of education best suited for an engineer. Of late years several of our colleges have devoted a special branch of their teaching to engineering classes, and the increasing area of scientific requirements renders it desirable that a yet wider field should be given to that class of instruction. It is obvious that pupils should be made acquainted with the principles which lie at the foundation of engineering science, and with the nature and property of the materials employed before they can enter with advantage upon actual work, which consists in applying those principles and those materials to practical use. The numerous colleges directed to this class of teaching in France, Germany and Switzerland, give to the engineers of those countries some advantages over us in this respect.

It is true that the best teaching will be given in vain to those who do not possess the qualities of mind fitted for their avocation; neither will any preliminary education suffice unless it is accompanied by active observation and subsequent continued self instruction.

Lord Shaftesbury, in a recent Paper, remarks, "that having given to every one the elements of knowledge, you have given him access to the means of acquiring more;" and he adds, "I am convinced that after all the best education a man gets is that which he gives to himself by his own exertions."

There are many instances where power of observation and self-instruction have enabled men to rise without much other teaching. Young men taken from ordinary schools and placed at once as pupils in the workshop or engineering works, are mainly dependent for their progress on those powers of mind; and what they learn in that way, though laboriously obtained, is rooted and grounded in a manner which probably no other teaching can accomplish. But there can be no doubt that their path would be made easier, and the scope of their observation wider, by previous education specially directed to the class of subject with which they have to deal. So far as my experience extends with regard to pupils, those who have come from colleges where applied science is taught, take at once a higher position, and have a much larger sphere of usefulness than equally clever men who have not had that advantage.

In the early days of this Institution the knowledge of the strength of materials, and the laws which govern mechanical action and forces was very imperfect. We had many theories based on assumed but not always correct data, and we had many valuable experiments upon which useful but empirical rules had been founded. Smeaton, Telford, Rennie, Tredgold, Buffon, Beaufoy, and others

contributed much to the knowledge existing at that time.

My father's essay on the strength and stress of timber appeared in 1817. This book went through many editions under the title of Barlow's Strength of Materials. It owed its popularity and success to the great want of systematic information which prevailed at that time, and to the fact that besides containing clear mathematical investigations of the several questions, it also contained concise rules for their application, written in simple language such as any well-educated workman could read and understand.

It is curious to observe that until that work appeared, it was still a disputed point whether the deflection of a beam strained transversely varied as the square or as the cube of the length, Bernouli's investigation giving one result, and Girard's so-called experiments giving another. My father made a totally independent investigation, accompanied with a series of clear and conclusive experiments, and thus put this question at rest for ever.

This fact is one among many which might be cited, showing the necessity of carrying on investigations of this nature, not by theory alone, nor by experiment alone, but by both, so as to check and establish every point of the inquiry.

Professor Rankine, in his address to the Senate of the University of Glasgow in 1855, refers to the antagonism between theory and practice. He attributes its origin to the ancient Greek philosophers who, in regard to physics and mechanics, entertained the fallacious notion of the existence of a double system of laws; one theoretical, discoverable by contemplation and applicable to celestial bodies, the other mechanical, discoverable by experiment and applicable to terrestrial bodies. And he goes on to show how the science of motion founded by Galileo, and perfected by Newton, overthrew this supposition and proved that celestial and terrestrial mechanics are branches of one science.

That some relics of this antagonism are yet to be found is true. There is a class of practical men who reject the adoption of any principles except trial and error. But there are others, and a class daily growing in numbers, who are desirous of availing themselves of theoretical knowledge. Among this class it is not a question of antagonism, but rather want of confidence arising from the existence of theories founded on ideal or insufficient data.

There was, for example, a theory of the arch, of which an account is given by David Gregory, in which it was assumed to be necessary that the line of pressure should coincide with the intrados of the arch. Another by La Hire and Attwood, called the wedge theory, in which it was assumed to be necessary that the pressure should be at right angles to the surfaces of the voussoirs. And it was not until the subject was taken up by Coulomb, and further elucidated by Professor Mosely, that we had a theory based on the conditions existing in a real arch.

Again, in the case of the solid beam strained transversely, Galileo, who, as we are informed by history, had his attention drawn to the subject during a visit to the arsenal and dockyard of Venice, promulgated a theory in 1633 assumed to be dependent on pure mathematical principles. This theory afterwards illustrated by Girard in his "Traité Analytique de la resistance des Solides," is thus commented upon by my father:—"Nothing can be desired more simple than the results obtained by this theory; but, unfortunately, it is founded on hypotheses, which have nothing equivalent to them in nature."

The errors of Galileo's theory were first pointed out by Mariotte, who subjected it to the test of experiment. Then followed Leibnitz, who applied to it Dr. Hook's law of "ut tensio sic vis," but he restricted it to the action of tension, treating the fibres as incompre hensible. Bernouli then took up the question, contending that part of the fibres were compressed and others extended. For some reason, probably because his results did not accord with experiment, he doubted the universal application of Dr. Hook's law. But this law, which is found to be perfectly consistent with experience, when applied to direct tension or direct compression within the limit of elasticity, is again had recourse to by Dr. Robinson, who next follows up the investigation, and by him the subject of the neutral axis is introduced, leaving its position undetermined.

The theory of the beam thus left has proved a misleading theory. Tredgold was misled by it while endeavoring to deduce the tensile strength of cast iron from bars of that metal strained transversely; the computed result giving him a tensile strength of 20 tons per inch, whereas it is only 8 by experiment. My father, who had ascertained the tensile, compressive, and transverse resistances of wrought iron, was misled by this theory into the supposition that the position of the neutral axis rose during strain above the center of gravity of the section.

Subsequent experiments of my own ('Phil. Trans.' 1855), made on large rectangular beams of cast iron and wrought iron, proved by actual measurements that the neutral axis was in the center of gravity of the section, and remained there throughout all the degrees of strain applied.

The subject of the transverse strength of beams has recently been treated in a valuable paper of Mr. Charles Emery, of New York, who suggests certain hypotheses which may lead to an amended theory. But we are still left without any adequate explanation by theorists of those causes which render a solid beam, whether of cast iron, wrought iron, or steel, so much stronger than the present theory of the beam would give it, as deduced from the tensile strengths of those materials.

In looking at the great progress of engineering science during the last half century, it will be observable that some of the most important advances have arisen in this country; among them, the application of steam to locomotion on railways, and in ocean navigation; the employment of wrought iron for ship building and for large girders; the screw propeller, the utilization of the powers of electricity for telegraphs and electric lighting, and the production of modern steel.

But while we seem to possess in a high degree the power of initiating great and practical ideas, other countries are quick in adopting them, and in many cases improving upon them, so that we receive back from them new applications and adaptations of the greatest value, as well as many new and useful inventions of their own.

It is in fact impossible to study the works of our foreign brethren without feeling, not only in regard to the magnitude of some of these undertakings, but also as to the excellence of their execution and the fertility of resource displayed in overcoming local difficulties, that we have now to deal with competitors with whom it will tax our best energies to keep pace; and in the varied conditions encountered in foreign countries, new and modified methods of treatment arise with which it becomes desirable that everybody connected with this Institution should be kept informed.

It is with this object that the Council, ably aided by their Secretary, Mr. Forrest, have, of late years, appended to their printed papers and discussions, extracts from foreign publications containing descriptions of works, and condensed extracts from engineering Papers of foreign countries.

To me it seems of great importance that our engineers, many of whom must look in the future to employment abroad, should be well informed of what is passing in other countries; and though much may be done to supply this information by books, and by the perusal of the valuable engineering periodicals of the day, yet, where practicable, a visit to the engineering works of other countries and an examination of them considered in reference to the resources available for their execution, and a personal acquaintance and interchange of ideas with the engineers themselves, brings with it elements of instruction of the greatest value.

Many of us have the advantage of acquaintance with the more important engineering works in Europe, but there is perhaps no country which presents such varied and extensive information as the United States of America. It became my duty in 1876 to go to America as one of the judges of the Philadelphia Exhibition, and I cannot only speak of the great amount of valuable information to be obtained there, but also of the hearty welcome with which English engineers are received by their American brethren.

American engineers are in advance of those in this country in regard to the application of steel in engineering structures. In Mr. Eads' great bridge at St. Louis of three arched spans, the center opening being 520 feet and the side spans

nearly as large, the arches are made of steel. And in a recent large railway bridge, erected at Glasgow, U.S., by General Sooy Smith, the entire structure is of steel. We have also seen by Mr. Clarke's valuable paper on large span iron bridges, read during the session of 1877, how carefully the study of iron open-work girders has of late years been applied in America, and the numerous opportunities which that great country offers for large works of that description.

In endeavoring to put before you some of the results of engineering progress during the last fifty years—results which have come more or less under my own observation—I am well aware how much has been omitted. Irrigation, mining, and numerous improvements in machinery, afford ample topics and examples of the general advance.

Taking Sir John Hawkshaw's estimate in 1875 as a basis, adding the probable cost of steamships, and allowing for the extension of railways, telegraphs, docks, harbors, and other works since that time, the total capital invested in engineering works cannot have been less than 3,500 millions, or about 70 millions annually; of which about $\frac{1}{20}$ appear to belong to railways, steamships, docks, harbors and telegraphs, all of which are directed to improving and extending the means of transport for passengers and merchandise and the communication of intelligence.

It is observable also that this great progress, which probably exceeds that of any like period in the history of the world, is due to improvements, new applications and discoveries, which are the result of experimental research and greater knowledge of natural laws. Beginning with some ascertained scientific fact as the power of steam or the transmission of motion by electricity, the advance made by one man becomes the starting point of another; and thus step by step we have been led up to the point at which we have now arrived, and past which we are traveling rapidly to further developments in the future. Thus railways, telegraphs, steam navigation, and other large achievements, in the advanced form in which we now find them, can neither of them be assigned to the credit of any one man, but they represent the cumulative result of the genius and perseverance of numerous individuals.

This Institution is justified in regarding with satisfaction the number of contributors to this advance who are found among its present and past members; and if there is any one class more than another to whom we stand indebted, it is to those men, both within and without the profession, in foreign countries as well as in our own, who by study and experimental research are continually adding to our knowledge of the powers of nature; those powers, the application of which to the uses and conveniences of man constitutes a fundamental element of the Charter of this Institution.

DYNAMO-ELECTRIC MACHINES.

From "Engineering."

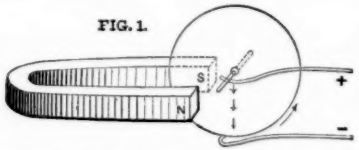
I.

Monsieur Antoine Breguet, of the well-known Parisian firm of telegraph engineers, has recently published a series of very important researches on the theory of the Gramme machine and other forms of dynamo-electric and magneto-electric generators, in the course of which he arrives at some extremely interesting results, and clears up a number of points which hitherto have been comparatively obscure in the operation of such machines. Starting from first principles and the simplest experimental data, M. Breguet propounds the successive steps of a logical chain of reasoning to link the grand discovery by Faraday of megneto electric induction with the applications of the principle in the machines of Gramme and Siemens. He is thus enabled to explain a point hitherto supposed irreconcilable with theory, namely, the practice of electrical engineers in setting the "brushes" or collectors of the current in the dynamo-electric machines in an oblique position against the commutator, and unsym-

metrical with respect to the field magnets of the instruments. He not only explains this, but points out that it is an absolute necessity of the case, and that upon this position will depend whether the machine is better suited to be a generator or an electro motor. He further explains for the first time the real *rôle* played by the ring of iron in the armature of the Gramme machine. And lastly he elucidates the action of the Siemens machine, and shows that there is at least one method of winding the wires upon its armature superior to that adopted hitherto in practice. It is proposed to treat in the present article of the earlier and more general portions of M. Breguet's research, reserving an account of his work on the Gramme machine and on the Siemens machine for subsequent occasions.

The first principle laid down by M. Breguet is the essential *reversibility* of the Gramme and all other dynamo and magneto-electric machines. Rotated by mechanical means, they supply a current of electricity derived from the energy of a steam engine or other motor. But if you supply them with a current of electricity they will, conversely, rotate and turn the electricity back into mechanical energy. The same thing is true of all electro-magnetic engines or electro-motors, such as those of Ritchie, Page and Froment. They are intended to rotate by electricity, but if you rotate them by mechanical means they will furnish in turn a current of electricity.

FIG. 1.



This principle of reversibility extends even to some unsuspected cases. Very early on in the history of magnetism, Barlow found that he could cause a wheel or disc of copper to rotate between the poles of a magnet, by sending a current at the same time perpendicularly through the disc from the axis to the circumference, where it passed into a pool of mercury arranged to make electric contact with as little friction as possible (Fig. 1). In 1831 Faraday performed the converse experiment, and found that by mechanically rotating a copper disc between the poles of a magnet, he thereby generated a current in a wire, the two ends of which touched the circumference and the axis of the wheel which were amalgamated over with mercury so as to insure better contact with the wire (Fig. 2). Here then is the simplest kind of electro-motor and dynamo-electric generator, and it illustrates at the outset the important principle of

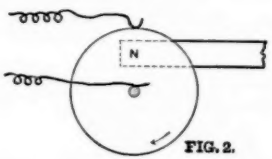


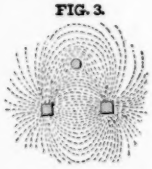
FIG. 2.

reversibility. The second matter which claims notice is the mutual interaction of a magnet and a conductor which carries a current. We sometimes speak loosely of the displacement of a current caused by a magnet when we mean that the conductor carrying the current is displaced. Although the term is convenient, it is scarcely accurate; for we must distinguish between mechanical force, or that which tends to move matter, and electro-motive force (so-called), which tends only to move electricity in a conductor. The mechanical reactions between magnets and current conductors which turn machines are obviously of the former class. These reactions, therefore, deserve to be studied from a nearer point of view, by applying a principle enunciated by Faraday concerning magnetic attractions, and lately further extended by Professor S. Thompson, to the case of the attractions between currents. Faraday first recognized the significance of the so-called lines of magnetic force, which are seen crossing in curves through every magnetic field when iron filings are sprinkled over it. Without necessarily attributing to these lines any physical existence, we may conveniently employ them as Faraday did, to investigate and to describe the actions between magnets or magnetic bodies. Faraday laid down the following properties as those possessed by these lines of force: Firstly, the lines of force tend to shorten themselves.

Secondly, lines of force lying in the same direction side by side repel one another. To these M. Breguet adds that a line of force, when it passes through iron or other metal capable of magnetic susceptibility, must be regarded as if shorter than one of equal actual length passing through air, so that the "tendency to shorten" may exhibit itself by a tendency to run through a magnetic substance near at hand.

By means of these simple principles Faraday was able to deduce the laws of magnetic attraction and repulsion from the figures formed by the lines of iron filings, when sprinkled over the magnetic field whose properties were thus to be investigated. Professor Thompson applied the same reasonings to the case of the attractions and repulsions exerted between two currents, and between a current and a magnet—in a research of which we gave some account to the readers of *Engineering* a few months ago.

FIG. 3.



One of the figures obtained by Professor Thompson (*vide* Fig. 3) enables us to study the action of Barlow's wheel; and this figure M. Breguet takes as the basis of his theory of the dynamo-electric machines. The two square spots show the poles of the magnet, and a point a little way from them represents a metallic conductor perpendicular to the plane of the figure, and traversed by a current which passes downwards through the round spot. This current produces a magnetic "field" all round it, which if the magnet were not present would consist of lines of force disposed in concentric circles. But in presence of the magnet and its radiating lines of force there is a mutual reaction, the nature of which can be learned by simply looking at the figure formed by the iron filings. The tendency of the lines to shorten would assuredly urge the conductor towards the poles of the magnet: and in Barlow's wheel, where this goes on continually in the part of the disc lying between the axle and the mercury cup, the simple attraction becomes a movement of rotation. A current passing in the opposite direction through the wire would obviously be urged in the contrary direction, or away from the magnet. Conversely, if the conductor were mechanically moved further away from the magnet, a current would be generated of opposite direction to that which caused the motion, the electromotive force of the current being proportional to the number of lines cut by the conductor in a second of time.

Following M. Breguet we next pass to a consideration of the first and simplest of electro-motors, as shown in Fig. 4.

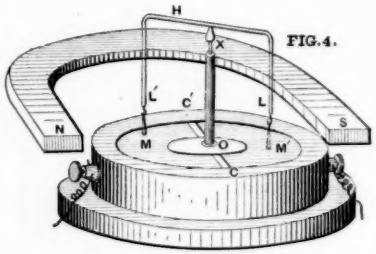
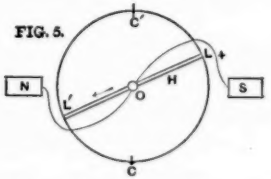


FIG. 4.

This apparatus consists of a metallic conductor bent twice at right angles and balanced on a center at a point X. The vertical branches carry little metallic-jointed appendages which dip into the halves of a circular mercury cup divided across by a diametral partition into two portions connected respectively with the poles of a battery; and the whole is placed between the poles N S of a magnet, so placed that the line joining the two poles is at right angles to the diametral line. The conductor rotates upon its center so long as the current passes. We may consider separately the action of the magnet on the two vertical portions L L' and on the horizontal portion H. The action upon the two vertical portions of the conductor is best studied by taking a plan of the apparatus, as shown in Fig. 5, which gives in diagrammatic outline all the working parts. The arrow indicates the direction of the current, which therefore ascends at L and descends at L'. Comparison between the conditions which here exist,

and those which gave the magnetic figure, Fig. 3, with iron filings will show a series of lines of force, of which the most characteristic will be the S-shaped curve shown by the dotted lines. Hence the tendency will be to displace L^1 towards the top of the figure and L towards the bottom, and their positions of equilibrium will be respectively C^1 and

FIG. 5.



C. But if the inertia of movement carry the contact breakers past these points and make them touch the opposite mercury cups, the current will be reversed, L being drawn towards C^1 and L^1 towards C. Hence there will be a continuous rotation, the direction of the current in the conductor being reversed at every half revolution, when the moving wire passes through the position of equilibrium at CC^1. A little consideration will show that the action upon the horizontal portion H is similar, and adds itself to the forces producing rotation.

Now suppose that instead of the simple wire bent twice at right angles, a conductor be taken having the vertical branches prolonged into two arcs, and carrying, as in Fig. 6, four little jointed

FIG. 6.

contact pieces. We shall now require the mercurial cups to extend over 90° of arc, *i.e.*, extending from C^1 only as far as S, and from C only as far as N. Had we taken eight little contact pieces, each mercury cup need only have occupied one-eighth of the circle or 45° of arc. If the number were indefinitely increased, then the arcs subtended by the mercurial contact cup might be diminished by the mere points C^1C. These considerations hold equally good in the converse cases where the instrument is used as a generator of currents.

One further step remains to be considered before we pass on to the application of these matters to the Gramme machine. Instead of the single wire we may take a wire coiled upon a frame, as in Fig. 7, and having many turns. On each wire of this coil there will be a similar action, hence the total force of rotation will be proportionately greater when an equal current is used. In all the various arrangements hereafter to be described, every single wire may be considered in a similar way to represent a coil, and hence the figures may be made as simple as possible. It will be noticed that the single flat coil of Fig. 7 if wound upon an iron spindle and frame virtually constitutes an armature of the type introduced by Siemens, and applied by him in the early magneto-electric machines, and also recently employed by M. Marcel Déprez in the excellent little electro-motors which he has constructed.

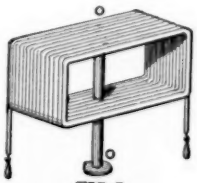


FIG. 7.

M. Breguet starts from two simple principles, viz: that every dynamo-electric machine or generator can be used as an electro motor or electric engine, and *vice versa*; and that a study of the distribution of the lines of force in their magnetic field will enable us to determine the best conditions for the action of such machines and motors.

We have now to pass on to a consideration of one of the very interesting applications which M. Breguet has made of his theory to the study of the Siemens dynamo-electric generator. This machine, which is familiar to the readers of *Engineering* from the article which we published upon it on a recent occasion, is the joint invention of Dr. Werner Siemens and of Herr Hefner von Alteneck. The special feature in it, the armature, with its peculiarly wound coils, of which we shall presently speak,

is due to the genius of the latter gentleman, and is in consequence sometimes spoken of as "Alteneck's armature," to distinguish it from the earlier and simpler longitudinal armature with cross-section like a double headed T, employed in the older Siemens machines.

Not to anticipate, however, we must return to the logical order of development pursued by M. Breguet; and must refer at the outset to the very simple machine figured (Fig. 4), in which a single wire bent twice at right angles is made to rotate electro-magnetically between the poles of a horseshoe magnet. A current enters this wire by a mercury cup at one side, and leaves it by a similar cup at the other; the direction of the current through the wire being automatically reversed at every half revolution as the wire swings round, thus alternately attracting up the wire towards the pole of the magnet and repelling it as it passes away on its circular path.

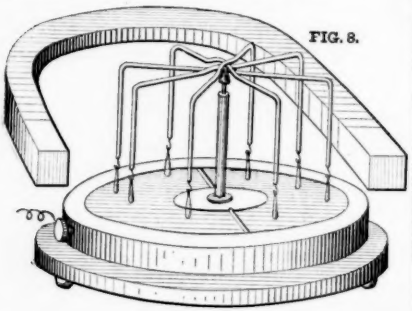


FIG. 8.

Suppose next that four such wires are suspended around the same pivot, and disposed so as to make equal angles with one another, each extremity of each wire being provided as before with a small contact-piece (Fig. 8). What are now the conditions of rotation? A little consideration will show us that if the mercury cups extend as before, and as in Fig. 9, to 180° on each side, the arrangement will be in every way inferior to the one formerly considered; for the current is now shared between four conductors, in each of which there will be but one-quarter of the total current, and they cannot all be situated in the most advantageous position of the field where the attraction or repulsion of the magnet is the greatest. Moreover, some of them will positively be pulled forward while others are pulled backward. So though the current is just as strong as before, the altered distribution of the current is wholly disadvantageous, and the apparatus is both worse and heavier than before. Suppose, however, that the mercury cups are diminished till they subtend, as in Fig. 10, angles of but 90°, only two of the conductors can dip simultaneously into the cup, and one will enter it just as another leaves it. Hence half the current will now traverse each; and if the sectorial mercury cups are judiciously placed so that their edge of first contact lies along CC′, which we may call the "diameter of commutation," at right angles to the line joining the magnet poles, the two conductors in contact can never be far from the point where the attractive force of the magnet field will have the largest effective leverage upon them. Better still will the machine be if the mercurial sectors are still further diminished, as in Fig. 11, down to 45°. Now only one conductor can dip in at once,

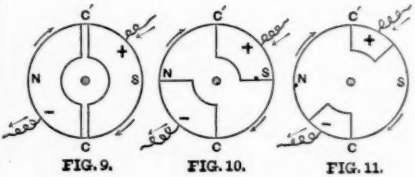


FIG. 9.

FIG. 10.

FIG. 11.

but it will take the whole current, and as it passes out of contact the next will pass in. The increased weight of the fourfold conductor over the single bent wire of the first arrangement is more than compensated for by the advantage of always having in the most advantageous part of the field that conductor which is being acted upon. Instead of simply receiving an impulse once every half turn, the impulses come eight times during every revolution, and the rotation will therefore be much more uniform.

Once more let us remember what was pointed out in a former paragraph, namely, that every single wire we have considered may be replaced by a coil of many strands, and we shall realize the advance now made towards an efficient electro-motor.

Here, also, we may pause to note that

if by the principle of reversibility we use mechanical power to rotate this system of conductors (or "armature" as we may call it), as it lies in the magnetic field, we shall obtain induced currents. And this new generator will possess corresponding advantages over the simpler arrangement that had only one bent wire, inasmuch as it will give both a stronger and a steadier supply of electricity; there being now eight successive currents generated during one revolution instead of two as before, and these currents will be more powerful, since the conductors in which they are generated are being moved through the most advantageous region of the field.

It is of course unnecessary to suppose the contacts to be made by cups of mercury, except that for light experimental bits of apparatus, the freedom from friction thus gained is of service. If the eight ends of these wires were brought down and soldered to a metallic collar on the axis, the collar being slit into eight separate parts, each of which successively came into contact with metallic brushes occupying the position relatively of the sectorial mercury cups, the same end would be attained, though with a little increased friction. With a larger number of conducting wires, the number of segments of the metallic collar or commutator would be increased, and their angular width proportionally diminished. This is in fact the kind of "commutator" which is used upon almost all the dynamo-electric generators in use.

THE recent announcement that the diamond has been artificially produced will doubtless call forth many interesting historical sketches relating to earlier labors in this direction.

Not the least important among these will be the forthcoming memoir of Samuel Brown the chemist, compiled by his brother John Croumbie Brown, LL.D.

As early as 1837 the young experimenter, being then only 20 years of age, began original researches in chemistry, and directed his efforts towards the crystallization of carbon.

Some of the results obtained are described in another place in the present issue. His labors, which ended at his death, in 1856, were largely in the direction of establishing the identity between carbon and silicon.

This memoir will prove a valuable bit of history if it should prove that a method, by means of which success has been reaped now, was employed with similar success some years ago.

To establish an identity between carbon and silicon is of course a problem of another kind, and one which is regarded by scientists generally as of impossible solution.

These allotropic forms of both elements are described in common textbooks, and a general parallelism in physical properties is well known. But any approach to identity between the like forms has been regarded as impossible as any transmutation of the metals.

REPORTS OF ENGINEERING SOCIETIES.

ENGINEERS' CLUB OF PHILADELPHIA.—The last number of the Proceedings contains the following papers:

XVIII. On Ganguillet and Kutter's Formula for the Flow of Water, by Thomas M. Cleeman.

Discussion of Paper XIV: Proper amount of Water-Way for Culverts, by Thos. M. Cleeman, Chas. G. Darrach, Rudolph Hering.

XIX. Progress of the Geodetic Survey of Penna, by Prof. L. M. Haupt.

XX. On an Important Legal Decision, by Percival Roberts, Jr.

Discussion on Paper XV: On the Connecting Rod, by Prof. Wm. D. Marks.

At the February meeting a paper was read on

The Light House System of the Delaware River from the head of the Bay to Philadelphia, by Mr. Edward Parrish.

THE BOSTON SOCIETY OF CIVIL ENGINEERS.—The late papers before this society have been:

The Production and Transmission of Power by means of Electricity, by Geo. W. Blodgett.

Rock Blasting and Machine Drilling, by Wm. Whittaker.

Some Difficulties Encountered in Sinking a Shaft for the Second Lake Tunnel at Chicago, by Eliot C. Clarke.

IRON AND STEEL NOTES.

ON HARDENING IRON AND STEEL: ITS CAUSES AND EFFECTS.—Knowledge of the effects of hardening, especially on iron, by no means complete, acquired increased interest through the Paris Exhibition, and from the Terrenoire exhibit of Siemens-Martin castings of extraordinary strength, and freedom from blowholes. At the meeting in Paris, Mr. Ackerman gave expression to the view that the reason

why the strength of undrawn Martin castings might be equal to that of drawn ingot metal of the same hardness, must be sought in the compression induced by the hardening. The present paper develops that view.

Different Modes of Occurrence of Carbon in Iron.—Commonly the carbon in iron is in two principal varieties—graphite and combined carbon—called dissolved or amorphous carbon. The graphite in iron is carbon mechanically incorporated with the iron. Combined carbon, when the iron is dissolved in boiling hydrochloric acid, escapes as carburetted hydrogen. If the iron, again, be dissolved in cold hydrochloric acid, a part of the combined carbon generally remains as a black residue. The quantity of carbon remaining undissolved when steel is dissolved in cold hydrochloric acid may be very different, according as the same steel was differently treated before dissolving. Raw steel undrawn gives a much larger residue of undissolved carbon than the same steel when rolled, and the latter more than when it is drawn out under the hammer. Finally, this residue of carbon is least to none at all in the well-hardened steel. If this well-hardened steel be heated anew it yields again a large residue of undissolved carbon, and this in a degree proportioned to the duration and intensity of the heating. These facts indicate that the so-called combined carbon does not occur in the iron always in the same way, and that drawing and hardening cause a more intimate union between the iron and the carbon; this union, on the other hand, being again relaxed by the renewed heating and subsequent slow cooling of the iron. It thus appears that the carbon commonly called combined ought properly to be divided into two kinds, viz., first, the carbon most intimately combined with the iron, which we, in accordance with Rinman's proposal, shall call hardening carbon, inasmuch as it characterizes the well-hardened steel; and, further, the carbon incompletely combined with the iron, which may be said to be in a sort of passage to graphite, and which Rinman called cement carbon, because it occurs in largest proportion in the undrawn raw or cement steel. It appears that the cement carbon is changed into the hardening carbon by heating to a red heat succeeded by a violent forcing together, continued until cooling is almost complete; while hardening carbon is changed into cement carbon by long-continued heating followed by slow cooling without extra compression. In the case of strong hardening of hard steel, we have the most powerful compression, for the rapid cooling produces a great difference of temperature between the outer and the inner layers of the piece, the more cooled exterior layers compressing the interior with greater force in proportion, partly as the latter are expanded by being more strongly heated, and partly as the limit of elasticity of the substance is high, so that there is not too great a loss of the compressing force by the extension of the exterior layers. Again, that hammering favors the conversion of cement carbon into hardening carbon, or the more intimate union of the carbon with the iron in which it occurs, more than rolling, may at least occasionally to some extent be attributed to the more powerful compression exerted by the hammer, but still more to the circumstance that the iron or steel, when the rolling is ended, commonly has a far higher temperature than when it has been drawn out under the hammer. For if the iron or steel be still red hot when the drawing is finished, a part of the carbon converted into hardening carbon, or more intimately united with the iron during the compression to which it has been subjected, may be again changed into cement carbon during the succeeding slow cooling. There is thus a very complete correspondence between the occurrence of hardening and cement carbon and their mutual conversion in malleable iron and steel on the one side, and the relations of the combined carbon and the graphite in pig iron on the other. It is not improbable that combined carbon may occur in pig iron also in two ways. A grey but not too siliceous pig may be converted into white pig iron by melting, followed by sufficiently rapid cooling. On the other hand, a white pig, somewhat rich in carbon, but not containing too much manganese or sulphur, may, by melting and superheating, followed by casting in a heated mould which cools with sufficient slowness, be converted into grey pig iron. But in order to change to grey a white pig of the nature described above, it is quite unnecessary to remelt it; for the greater part of its combined carbon may also be converted into graphite by a sufficiently long continued heating to a strong yellow heat, air and other oxidizing substances being excluded. Graphite, as such, cannot be found in the molten pig, for it must then, in consequence of its comparatively low specific gravity, rise to the surface of the iron, and form a deposit there; but in such a case this graphite is found not in, but upon, the pig iron. It thus follows that the graphite to be found in the solidified pig iron has not been able to separate itself sooner than immediately after solidification, and whether a pig becomes grey or white depends, besides the presence of other substances in the iron, just upon the rapidity of cooling at or immediately after solidification. This again depends on the degree of superheating of the pig iron, for the more superheated the pig iron then was, so much more heat has the mould been able to take up before solidification commences, and the slower consequently is the succeeding cooling. Thus also it is only by a long-continued heating to a temperature approaching somewhat closely to the melting point of pig iron that the white pig may, without re-melting, be converted into gray; but if the temperature be raised still further, so that fusion commences, the graphite which has been separated from the iron is again dissolved in it. On this must depend the fact that the fusion point of the grey pig is only about 100 deg. C. higher than that of the white, and thus so incomparably lower than the fusion point of steel or malleable iron, which have the grey pig's content of combined carbon, but altogether want its graphite. As in pig iron, with strong and long-continued heating, carbon is separated in the form of graphite, so heating, followed by slow cooling, favors the formation of cement carbon in steel.

As the cement carbon cannot be so intimately combined with the iron as the hardening carbon, but approaches in some degree to graphite, the supposition is easily arrived at, that the cement carbon cannot have so great an influence on the properties of iron as the hardening carbon; but until hardening and cement carbon can with certainty be distinguished, and some method has been discovered of quantitatively determining each of them, it is, of course, still too early to say anything with certainty on this point. In the near future we shall probably see that some of the great changes in iron and steel which have been induced only by different methods of treating the same material, are caused by the alterations in the proportions between hardening and cement carbon brought about by the method of working.

CONSOLIDATION OF FLUID STEEL.—This paper, by Mr. A. Davis, commenced by a brief notice of what has been done in compressing fluid steel by Bessemer, Whitworth and others, and then described the system of Mr. H. R. Jones, of the Edgar Thompson Steel Company, U.S.A., now in constant operation at the works of that company near Pittsburg. The process is very inexpensive, and consists in simply admitting steam at a high pressure to the top of the ingot mould immediately after the metal has been poured. A steam drum or receiver, communicating direct with the boiler, is fixed, for the sake of convenience, to the side of the ingot crane. This drum has a number of cocks, corresponding with the number of the moulds. India-rubber pipes are provided to conduct the steam, one end of the tube being permanently fixed to the drum, and the other by means of a coupling attached to the lid of the mould. The ingot mould has, at the upper end, a cone seat accurately turned, upon which the pouring cup rests, and which afterwards receives the lid, which is secured in position by means of a steel wedge. By this arrangement the cup is easily removed, and the lid—with coupling and flexible pipe attached—substituted, the cone seat forming a steam-tight joint. In practice a greater pressure than from 80 lbs. to 150 lbs. has not, Mr. Davis says, appeared to be necessary, the higher pressure being used for mild steels. Formerly at the Edgar Thompson Works, with a 14-in. ingot reduced to a bloom of 7¼ in. + 7¼ in., it was necessary to cut off from 30 in. to 36 in. (*sic*) of the bloom in order to arrive at a part free from piping, whilst under this process the ingots are free from porosity, and are turned out with a perfectly level top. Experiments made in order to ascertain the difference between an ignot cast in the ordinary way and one under pressure, have, it is stated, shown that the latter with the same quantity of metal from the ladle is from 1½ in. to 2 in. shorter than the former when cold. In addition to the consolidation of the ingot, the steam, acting upon the end, cools and hermetically seals the top of the ingot, saves the use of the sand or iron cap, and enables the men to deal with it ten minutes earlier without any fear of bleeding; and this allows the ingot to be conveyed to the reheating furnace with greater rapidity and in a hotter condition than formerly. It is also found that with the use of steam the ingot moulds last better, the average in 1879 being 95 ingots, or nearly 112 tons of steel per mould. The method of compression described in this paper has recently been adopted at the works of Messrs. Bolckow, Vaughan & Co.

RAILWAY NOTES.

THE Berlin correspondent of the *Standard* says that the Russian Government have been, and are, actually petitioning at Constantinople for a Bagdad railway concession. They have already been permitted to send out engineers to trace the route. Should they succeed in obtaining a final concession, it will be nominally given to General Tchernaieff. Besides this railway, several others are petitioned for by European speculators at Constantinople. A French company, acting in concert with some of the more strictly Romanist Bishops, is desirous to construct a line from Jaffa to Jerusalem. Russia has offered to connect Kars with Erzeroum in the interest of the White Czar. Englishmen have repeatedly advocated the scheme of a line proceeding from Alexandretto to Aleppo and Bagdad. Last, not least, General Klapka wishes to extend the Constantinople—or rather the Hyder Pacha and Ismid line—to Koniah Bagdad and the Persian Gulf. Without asking any pecuniary assistance, M. Klapka, to cover expense, insists upon all adjoining land being handed over to his company gratis. This condition the Turkish Government are willing to accord, provided nine-tenths of the soil so ceded are handed over to Mussulman colonists, and an agreement can be effected with Mr. Hansom concerning the Hyder Pacha and Ismid line. The difficulties in the way of such an arrangement have given French capitalists an opportunity for likewise putting themselves in communication with Mr. Hansom. What with the competing companies in the field, and the obstruction caused by the recent accession of a Russophil Cabinet at Constantinople, all these various schemes are still in abeyance.

IN a recent paper read before the London Association of Foremen Engineers by Mr. M. Reynolds, on practical engine driving, the author spoke of the blinding effect of the glowing white light of the engine fire, a brief glance into which, he said, rendered the person who looked for a time unable to recognize the colors of the signal lamps.

IT is now proposed to construct a railway by the Jarentaire and through the Col du Mont, instead of through Mont Blanc, by which it is computed that a saving of seven kilometres might be effected. The promoters, however, seem to forget that the object of a third Alpine railway is to compete with the Gothard line and retain for France the Anglo-Indian traffic; but from Calais to Brindisi the distance by Mont Blanc is 22 kilometers greater than by Mont Cenis, and exceeds by 160 kilometers the distance between Ostend and Brindisi by the Gothard.

Of the 346 axles which failed the first nine months of the current year, 178 were engine axles, viz., 164 crank or driving, and 14 leading or trailing; 16 were tender axles, 2 were carriage axles, 143 were wagon axles, and 7 were axles of salt-vans. 58 wagons, including the salt-vans, belonged to owners other than the railway companies. Of the 164 crank or driving axles, 124 were made of iron, and 40 of steel. The average mileage of 111 iron axles was 185,629 miles, and of 37 steel axles 153,608 miles. Of the 1,377 rails which broke, 1,258 were double-headed, 93 were single-headed, 12 were of the bridge pattern, and 13 were of Vignoles' section; whilst the section of 1 was not stated; of the double-headed rails, 785 have been turned: 1,168 rails were made of iron, and 209 of steel.

In writing of the new fast train of the Paris, Lyons, and Mediterranean Company, the *Kölnische Zeitung* gives figures to show that the speed of this new express is not, as asserted, the greatest attained on the Continent, but is exceeded by that of several German trains. The Paris-Marseilles express makes on an average 66.3 kilometers an hour, or, including the stoppages, 56.2 kilometers. On the Lelviter line, between Berlin and Cologne, the distance of 583.2 kilometers is completed in nine hours 26 minutes, at a mean speed per hour, including stoppages, of 60 kilometers. Between Spandau and Stendal the mean speed is 71.8 kilometers per hour. On the Potsdam line, between Berlin and Magdeburg, a distance of 142 kilometers is traversed in 2 hours 7 minutes, including stoppages, at a mean speed of 67.9 kilometers per hour. The velocity attained on this line between Brandenburg and Magdeburg, a distance of 80.7 kilometers, is 69.15 kilometers per hour.

ENGINEERING STRUCTURES.

Great progress continues to be made with the St. Gothard tunnel. Three thousand workmen are engaged between Fluchen and Goeschenen, and sixty boarding and lodging-houses have been constructed for their accommodation. Next year 5,000 men will be gathered together in the same district, and a hospital has been specially erected at Wasen, supported to a large extent, like that at Altorf, by contributions from the *employés* themselves. Ten thousand kilogs. of dynamite are used every month at the works, and double that quantity of lime and cement every day.

A Portuguese gentleman has just submitted to the Government a scheme for embanking the Tagus twelve miles above Abrantes, so as to raise it to a sufficient level for being canalized and irrigating about 400,000 hectares of land on the banks. These branch canals would be several hundred kilometers in length, and the cost would be very moderate considering the enhanced value of the land, which he estimates at £24,000,000, or nearly one-third of the National Debt. The scheme and drafts are offered as an act of patriotism, without idea of remuneration, and the Government, it is thought, will refer them for full examination to Portuguese engineers.

The Simplon Tunnel.—Our French neighbors, recognizing the vast importance of the proposed Simplon tunnel to their commerce, have, during the last few months, been in negotiation with the Swiss Government, and a treaty similar to the one which was concluded in 1871 between Germany, Switzerland, and Italy, concerning the St. Gothard tunnel, will shortly be signed, by which permission will be granted to the French Government to subsidize the Simplon Railway Company to the amount of some 48,000,000f. M. Leon Say, the French Minister of Finance, arrived at Vevey on the 16th inst. to make a personal inspection of the site of the tunnel and of the works which have already been carried out, in order that he may possess full *connaissance de cause* in recommending his Government to grant the subsidy in question. The works alluded to consist of a line of railway lately completed and opened to traffic, which extends from Lausanne up the Rhone Valley to Brigue, at the foot of the Simplon—the very spot where it is proposed to pierce the tunnel. On the other side of the mountain, the Italian Government is engaged in constructing, at the cost of 28,000,000f., a line of railway which will unite Iselle at the southern end of the tunnel with Arona on the Lake Maggiore, the present northern terminus of the Haute Italie railways. The Simplon Railway Company are now, therefore, about to commence the tunnel which, when terminated, will complete the straight line of railway extending from Paris to Brindisi, *via* Pontarlier, Lausanne, the Simplon, and Milan, thus obviating the immense angle described by the Mont Cenis route. It may be remembered that the proposal to subsidize the Simplon route was already submitted to the French Chambers in 1873, when it was indefinitely postponed without discussion. This want of proper consideration must be attributed to several reasons. In the first place, the resignation of M. Thiers and other political events absorbed men's minds in France at that moment; secondly, the Compagnie de la Ligne d'Italie, in whose favor the concession had originally been granted, had just failed in an exceedingly discreditable manner, and had been wound up by order of the Swiss Government. Lastly, at that time, when the prospect of completing the St. Gothard tunnel was apparently hopeless, the Simplon route not only seemed to offer no very special advantages to French commerce, but even appeared in the light of a competitor with the Corniche and Mont Cenis Railways, nor were the Paris-Lyon-Mediterranée Railway Company in favor of the undertaking. Now, however, the aspect of affairs has entirely changed. Since 1874 a new company has been intrusted with the execution of the enterprise, and has given most satisfactory proofs of its activity by the completion of the railway up to the very entrance of the proposed tunnel at Brigue. Colonel Cérésole, formerly President of the Swiss Confédération, is the leading spirit and managing director of this company, and is encouraged in his work by the earnest support of such men as Gambetta, Grévy, Léon Say, &c.

Although the tunnel will be rather longer

than that of the Mont Cenis, or of the St. Gothard, it will be constructed and worked under very much more favorable conditions than either of them. The entrances to the St. Gothard and Mont Cenis tunnels are both situated at a considerable altitude—the former being at 1,152 meters, and the latter at 1,560 meters above the level of the sea. Consequently, costly zigzag and corkscrew lines of access have been resorted to, in order to reach the entrance of the tunnels, and owing to the very steep gradients, the power of traction required is something enormous. The Simplon tunnel, on the other hand, enters the mountain at its very base. The railway extending from Lausanne up the lower part of the Rhone Valley, is perfectly straight and without any curves, while the gradient nowhere exceeds 10 millimeters—1 in 100. At its exit on the southern side of the mountain, in the Diviera Valley, the gradient is somewhat stronger—13 in 100. In fact, when the tunnel is completed, the highest point of the line between Paris and Milan will not be in the Simplon, but between Dijon and Lausanne. Owing to the low level of the tunnel, the line will not suffer from the frequent interruptions which the snow causes in winter on the Mont Cenis and St. Gothard routes.

Competent geologists declare that the granite and rock of the Simplon are less hard and compact, and that the infiltrations are less serious than those of the St. Gothard and the Mont Cenis. The Rhone at the Swiss and the Diviera at the Italian extremity of the tunnel will provide the hydraulic power necessary for the boring, while, thanks to the temperate climate of the Valais, the works will not be exposed to the risk of being deprived of their motive power during severe winters, as were those of the Mont Cenis and the St. Gothard.

The tunnel will be 18½ kilometers in length, as compared with the 15 kilometers of the St. Gothard and the 12 kilometers of the Mont Cenis tunnels, and, as it is estimated that a daily advance will be made of 9 to 10 meters in the boring, we may look for its completion in seven or even six years' time. Eighty million francs are to be devoted to the undertaking, under the following items: 74,000,000f. for the tunnel itself, estimated at the rate of 4,000,000f. per kilometer. This estimate appears somewhat high when compared with that of the St. Gothard, which is being pierced at the rate of 2,500,000f. per kilometer. One million francs are required for the completion of the roadway in the tunnel, and 5,000,000f. for the construction of the great international station at Brigue, similar to that at Modane, on the Mont Cenis Railway.

Only a very small portion of this sum—viz., 13,500,000f., consists of stock subscriptions, the balance of 66,500,000f. being granted to the company in the form of the following subsidies:—4,500,000f. from the Swiss Federal Government; 5,000,000f. from the Government of the Canton de Vaud; 1,000,000f. from the Government of the Canton du Valais; 3,000,000f. from the Governments of the Cantons de Berne, Fribourg, and Geneva. A grant of 5,000,000f. from the Swiss Occidental Railway Company, which will derive great advantages from the undertaking; and, lastly, 48,000,000f. the subsidy about to be granted by France.—*London Times.*

ORDNANCE AND NAVAL.

GUNNERY EXPERIMENTS.—Sir W. Palliser writes to the *Times*:—"It may be interesting to some of your readers to know that my rifled 64-pounder gun of 58 cwt. has been disabled by a double charge—namely by 6 lbs. of R. L. G. powder and a 66 lb. shot rammed down on 6 lbs. of similar powder and a similar shot. The powder acted with exceptional violence. Some of those present considered that it had 'detonated.' However this may be, the barrel of the gun, though much bulged, is sound, while the casting or shell of the gun is cracked in several places. The thickness of the gun round the front charge is equal to the diameter of the bore. During a previous trial the same effect was produced upon a similar gun by a charge of 30 lbs. of R. L. G. powder and a shot of 150 lbs. weight. In fact, the same barrel has been used in each of the guns. The disabled gun is now being bandaged up with an iron hoop, and will shortly be fired with papier mâché wads to try the effect of jamming. I submit that one more instance has now been added to the proofs which have gone before that guns which are lined with coiled wrought-iron barrels do not burst, but only become disabled when subjected to excessive strains; and I feel convinced that the substitution of these barrels in the place of steel tubes would prevent any chance of wrought-iron guns being burst in similar circumstances. Looking to the fact that the action of gunpowder is much affected by various circumstances, and that in order to keep the pressures in large guns within due bounds it is actually necessary to make up the cartridges in a peculiar manner and to employ powders of different natures for different guns, it will be seen how difficult it may be to prevent the occasional occurrence of exceptional pressures in large guns. The question is thus one of great importance, and it will, no doubt, receive the attention it deserves." In a subsequent letter to the same journal, Sir W. Palliser adds:—"I should feel obliged if you would allow me to contradict an announcement which has recently appeared in most of the London papers to the effect that I instituted my experiments to oppose the opinion of the Thunderer Committee. I need hardly, I hope, say that my only object is to seek for the truth. I have now before me carefully prepared diagrams, showing the enlargements of the bore causcd in one gun by four, and in the other by eight rounds of double charges. In no case has the rear charge of powder caused the slightest expansion in the bore; whilst the expansions which have been caused by the front charge show that the pressures with pebble powder have been very great, and that the pressure due to the R. L. G. powder has been exceptionally violent. I have, therefore, much pleasure in correcting a former opinion which I had formed upon the results of experiments made with

muskets, and in stating that the opinion expressed by Captain Noble, and adopted by the Thunderer Committee, is correct as regards the pressure of a forward charge. I am, however, still of opinion that the bursting of the 38-ton gun has been due to a jam, and not to double-loading, and for the following reason: In every case out of 12 rounds with double charges the point of maximum pressure caused by the front charge of powder lay over that charge, and in the rear of the base of the front projectile; while in the Thunderer's gun the point of *maximum* pressure was situated in front of the place where the base of a front projectile would have been had there been one in the gun. As I have been frequently asked whether I believe that double-loading would burst the the Thunderer's gun, I should like to say that, if the gun were double-loaded, so that the front charge should lie in the position in which it was painted upon the outside of the burst gun, I think it would probably burst; but if the charge be rammed well home, then the front powder-charge will come within the coiled breech-piece, and the gun must be a worse gun than I believe it to be if it bursts. I submit that my experiments entitle me to say that a 38-ton gun made upon my plan would not burst under either of the above conditions.

[NOTE.—Since the above was written, the companion gun of the Thunderer has been burst by loading with a double charge.]

THE Secretary of the United States Navy, in his annual report on the condition and operations of the Navy Department for the fiscal year ending June 30, 1879, says:—"The condition of the Navy has greatly improved during the last year. There are now in commission thirty-five vessels, consisting of cruisers, monitors, and torpedo boats. Of the different classes, sixteen can be put in condition for sea service in a few months, and twenty could be made ready in an emergency. With this done, the fighting force of the Navy which might be made available in a very short time would consist of eighty-one vessels of all classes. And if to this number be added the four monitors, Terror, Puritan, Amphitrite, and Monadnock, and eight powerful tugs, which can be fitted for either cruisers or torpedo boats, our whole effective fighting force would consist of ninety-three vessels. The monitors could be completed, with the necessary appropriations, without much delay. Of the vessels now used as receiving ships, seven are unfitted for any other service. There are twenty-seven vessels unfitted for naval purposes of any kind whatever, but which are a positive expense, as it is necessary to keep in employment a force of shipkeepers to preserve them from entire destruction. Some of them might be profitably converted into merchant vessels, and it would be economy to sell the whole."

THE ST. GOTHARD TUNNEL.—The two sections of the tunnel were successfully joined on the 29th of February. The entire length is about $9\frac{3}{10}$ miles. The contract for this great work was awarded to M. Louis Favre, of Geneva, on the 7th of August, 1872, and the work on the Italian end was begun almost immediately. On the Swiss side the work was begun in November of that year.

The time allowed for the completion of the work was eight years, only seven and a half of which have elapsed. It is confidently expected that the road through the tunnel will be opened for traffic in October.

BOOK NOTICES.

ICE-MAKING MACHINES.—Translated from the French of M. Ledoux, Engineer of Mines. New York: D. Van Nostrand. Price, 50 cts.

This little book (No. 46 of Van Nostrand's Science Series, is a reprint from a series of articles first published in *Van Nostrand's Magazine*, and treats the subject from a purely scientific view; it bears on all its pages the stamp of the thoroughly mathematical mind that wrote it, and is characteristic of French scientists, who, as a rule, reason as thoroughly and as strictly mathematically as non-scientific writers are superficial, especially when they treat upon scientific subjects. The art of refrigeration is based on strict physico-mathematical principles, especially since the discoveries of modern science respecting the convertibility of heat into motion, or inversely, the possibility of lowering temperatures by the transmission of heat by means of proper appliances. The author does the subject justice in a mathematical point of view, and continually applies algebraic formulas, with which the book abounds; many of these formulas require a knowledge of the higher branches of mathematics to understand them. For this reason we fear the book will do little good among those in this country who search for information upon the subject. Mathematical knowledge is too rarely diffused, and very few, if any, will be able to profit practically by the truths which can be deduced from the formulas.

The book treats all the different classes of refrigerating machines first those based on compression and expansion of air, and only mentions Giffard's machine; the next class are those in which a volatile liquid is used, and among which are only mentioned sulphuric ether, sulphurous oxide, ammonia, and methylic ether; while the machines using chymogen or petroleum ether, bisulphide of carbon, and liquefied carbonic acid, which have attained some reputation in the United States, chiefly from a scientific point of view, are ignored, simply for the reason that they are not yet known in France; but as the laws are the same, the formulas used for the ethers are also applicable to the first mentioned, while those for ammonia may be applied to carbonic acid, of course with the proper correction of the boiling points, which are much lower in the last mentioned liquids.

Finally, those machines are treated which are based on what is here called "chemical ical action," but what we would only call "solubility." As the type mentioned, Carré's first ammonia machine acts by the strong solubility of ammoniacal gas in water, and in this

sense the refrigerating mixtures belong do this class, but these the author only omits.

The ultimate results arrived at are that, theoretically, from 1,200 to 1,500 negative caloric units may be obtained for every kilogram of coal burned, all which, when reduced to Fahrenheit units and pounds, means that for every pound of coal consumed we may subtract a quantity of heat equivalent to 4,000 or 4,500 units; this is about 80 per cent. above the results obtained in practice, so that only about 800 to 900 units of heat can actually be abstracted. The difference between theory and practice must be attributed to external losses of temperature, to imperfect action in the exchanges of heat, but chiefly in the expenditure of work in driving the pumps. If we consider that in the steam engine as much is lost, the ice machines, which are only in their infancy, are better than the steam engine, which has been in operation and improved upon for more than three generations.—*Manufacturer and Builder.*

REPORT OF THE TOPOGRAPHICAL SURVEY OF THE ADIRONDACK WILDERNESS OF NEW YORK. By VERPLANCK COLVIN. Albany: For sale by D. Van Nostrand.

Most lovers of the forests regard the Adirondack region as exhibiting in the fullest degree the characteristics of unreclaimed wildness. All the charms that belong to a wilderness that is nearly pathless, and that is covered by wild vegetation that is nearly impenetrable, will for a long time yet invest this region and tempt lovers of untrained nature to attractions they can scarcely find so accessible elsewhere.

The enormous wealth of this region in lakes, woods, mountains and wild game was not appreciated until the earlier reports of Mr. Colvin were published.

The last report covered the work of the year 1873. The present one extends from 1874 to 1879.

It is filled with maps and with statistical tables of heights and distances. It will be regarded as indispensable by all the frequenters of this charming region.

STEEL: ITS HISTORY; MANUFACTURE; PROPERTIES AND USES, by J. S. JEANS, Secretary of the Iron and Steel Institute. London and New York: E. & F. N. SPON. For sale by D. Van Nostrand. Price, $14.50.

This work bears the appearance of an encyclopedia, and a cursory examination of its index and its pages tends to the theory that it presents as complete an account of steel as can be gathered from the literature of the subject.

The work is divided into four sections indicated by the title.

The historical portion is again subdivided into chapters; each giving the history of steel-making in a distinct geographical region.

The section relating to Manufacture describes fully the many processes, and is illustrated by a good supply of plates and cuts.

The sections relating to Properties and Uses, are not wanting in interest nor completeness.

The author intimates that the work does not claim to be a metallurgical treatise. It is intended to aid the general reader, the statistician and the user of steel as much as the manufacturer; and if its main value should be found to lie in its historical qualities, such a result will only accord with its original design. The subject has been treated throughout with reference to giving it a popular as well as a scientific interest, on the presumption that the general public can hardly be uninterested about the development of one of the most remarkable industries of modern times. It is presumed that the value of the work is not thereby diminished to those who produce or select materials for construction.

The book contains 858 pages, and is illustrated by 23 plates and 186 wood cuts.

THE CAR-BUILDERS DICTIONARY. By MATHIAS N. FORNEY, M.E. New York: Railroad Gazette. For sale by D. Van Nostrand. Price, $2.00.

This is an illustrated dictionary in the fullest sense of the term, every separable part of a railway car is defined and illustrated by a woodcut. The work was compiled for the Master Car-Builders Association, and was rendered necessary by the differences in the nomenclature employed by car builders in different parts of the country. Thus the Draw-bar is known as Pull-iron, Shackle-bar and Bull-nose respectively, in as many different sections.

The compiler makes conspicuous acknowledgements of the assistance of Mr. Garey of the N. Y. Central & Hudson River Railroad, and of Mr. Calvin A. Smith, of the Master Car-Builders Association.

AN HISTORICAL SKETCH OF HENRY'S CONTRIBUTION TO THE ELECTRO-MAGNETIC TELEGRAPH: WITH AN ACCOUNT OF THE ORIGIN AND DEVELOPMENT OF PROF. MORSE'S INVENTION. By WILLIAM B. TAYLOR. Washington: Government Printing Office.

A new interest attaches to the early progress in Telegraphy in these times of rapid development of electrical science, and while this interest is enlivened is a fitting time to present to the general reader the history of the earlier progress in this direction, and to assert the lawful claims to distinction of those scientists to whom the world is indebted.

Most of this history has only been previously presented in a fragmentary manner in magazine articles, or else in exceedingly brief form in text books on electricity.

The present sketch is timely and will doubtless be widely read.

MISCELLANEOUS

TEMPERATURE OF TOWN WATER SUPPLIES. A paper was read on this subject at the recent meeting of the British Association by Mr. Baldwin Latham, in which attention was drawn to the fact that the temperature of the water-supply of a town, as furnished by public waterworks, was totally independent of the temperature of the water at its source of supply, and that invariably the temperature of the water is the temperature of the ground at any season of the year at the depth at which the

distributing mains were laid. The average temperatures throughout the year, whatever the source or mode of supply, varied very little, but there was great difference in the range of temperature, and that while temperature in the chalk wells at Croydon gave an average monthly range, based upon daily observations, of 0.64°, the same water when supplied direct from the mains gave an average monthly range of 21.14°, or when stored in a cistern a range of 28.05° ; while water supplied from the Thames in Westminster gave an average monthly range of 24.69°, but the average yearly difference of temperature between the chalk water supplied at Croydon and the Thames water supplied in Westminster was only 0.67°

ARTESIAN WELLS IN CENTRAL AUSTRALIA. Successful borings for water have been made in Frome County, South Australia, in a district hitherto almost devoid of surface water, and regarded as consequently almost worthless for agricultural or pastoral purposes. One well, sunk in some arid country near Lake Frome, at a distance of 400 miles north of Adelaide, as the crow flies, which has been bored to the depth of 370 feet, produces a daily supply of 10,000 gallons of excellent water ; and other artesian wells in the same district have proved equally successful. As the result of the enterprise, we are told that, whereas that country would formerly only carry a few thousand head of stock, its capabilities are now practically unlimited. This success will stimulate similar enterprise elsewhere. Much of the so-called desert country forming the boundary between the coast district and the rich pastoral lands which have been discovered in the interior of the continent will be reclaimed by this means. The South Australian Government is sending a scientific expedition to the shores of the Great Australia Bight, with a view to the selection of proper sites for artesian wells to tap the deep springs which are known to exist there ; so that a part of the country which has hitherto been regarded as almost the most inhospitable portion of Australia will, by this means, says the *Colonies and India*, be thrown open to agricultural enterprise.

INCOMBUSTIBLE WOOD.—M. M. P. Folbarri claims that he has discovered a method by which wood of any kind can be rendered incombustible. The following chemical compound is said to produce the result :—Sulphate of zinc, 55 lbs. ; American potash, 22 lbs. ; American alum, 44 lbs. ; oxide of manganese, 22 lbs. ; sulphuric acid of 60°, 22 lbs. ; water 55 lbs. ; all of the solids are to be poured into an iron boiler containing the water at a temperature of 45° C., or 113° F. As soon as the substances are dissolved, the sulphuric acid is to be poured in little by little, until all the substances are completely saturated. For the preparation of the wood, it should be placed in a suitable apparatus, and arranged in various sizes (according to the purposes for which it is intended) on iron gratings, care being taken that there is a space of about half an inch between every two pieces of wood. The chemical compound is then pumped into the apparatus, and as soon as the vacant spaces are filled up it is boiled for three hours. The wood is then taken out and laid on a wooden grating in the open air, to be rendered solid, after which it is fit for uses of all kinds, as ship-building, house-building, railway carriages and trucks, fence-posts, wood-paving—in short for any kind of work where there is any liability to destruction by fire.—*Building News.*

BREAKING ICE WITH DYNAMITE.—Some experiments of this order were recently made on the Seine, near the Pont des Invalides, in presence of a large crowd massed on the quays. Two civil engineers, MM. Bernard and Lay, directed operations, and they were aided by MM. Flegy and Streits, of the Noble Dynamite Company. The experiments were six in number. In the first, a cartridge of 80 grammes on a float placed in a hole of 20 centimeters diameter, was exploded with a Bickford fuse ; it enlarged the hole 75 centimetres, and cracked the ice to a length of 6 metres. The second cartridge of 250 grammes, placed similarly under the ice with a Bickford fuse, projected vertically to a great height a mass of water and *debris*, and dislodged nearly 100 cubic metres of ice. The third experiment, which was the most important, was made with three cartridges of 406 grammes, each connected by conducting wires with an electric machine on the bank. The portion of ice shattered was about 80 meters long by 5 to 6 metres broad. This experiment seems to have indicated the right way to follow, for not only was a large quantity of ice separated from the mass, but it was in very small pieces ; this would obviate agglomeration against the arches of bridges. The three remaining experiments were made with cartridges of 400 grammes, exploded with the Bickford fuse. The dislocations were about 15 to 20 metres in extent, which can be doubled by introducing levers into the fissures produced by the explosion.

GOLD IN RUSSIA.—The St. Petersburg papers report a great development of the gold production of Russia. Strata containing gold in considerable quantity have recently been discovered in the Ural Mountains. It is said that in the district of Sennigsei, a Russian proprietor has found in his gold mine, near Motygynn, a nugget 445 lbs. in weight, representing a value of nearly £15,000.

THE deepening of the Seine between Rouen and Paris, which will materially encourage the importation of English coals into Paris, is exciting a good deal of dissatisfaction among the coal-owners of Pas-de-Calais and Nord. Among several schemes for improved water-way from the north to Paris, the one which appears to find most favor is that which commences at Haute Deule, near Noyelle-Godault, passes near Arleux, Peronne, Ham, Noyon, and Méry-ser-Oise, reaching Paris at the Villette basin. This route is not only the shortest between the coal fields in Paris, but it will also give greatly increased facilities for obtaining cheaper coals at Amiens and Beauvais. The coal owners are desirous that the canal and locks should be of sufficient width to accommodate vessels of 500 tons. The estimated cost is 74 1-2 million francs.